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[*Authors alone are responsible for all opinions expressed in their Communications.*]

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No. 37.

AWARD OF THE BOYLE MEDAL TO PROFESSOR PAUL A. MURPHY, Sc.D.

1932.*

REPORT OF THE COMMITTEE OF SCIENCE AND ITS INDUSTRIAL APPLICATIONS.

MURPHY'S first contributions to science were made under the guidance of Dr. Pethybridge—who is also a Boyle Medallist—in the years 1911 to 1913. This joint work on some of the bacterial and fungous parasites of the potato is best known by their contributions to knowledge of the genus *Phytophthora,* especially the potato blight fungus and its long-sought resting spores. Later on Murphy independently returned to this general question, and gave a detailed account of the morphology and cytology of the sexual organs of a *Phytophthora* with amphigynous — this now common term is his — antheridia, the original discovery of which was due to Pethybridge. Still later, Murphy announced the discovery for the first time of the resting spores of the potato blight fungus in nature—an example of a novel observation of importance in a field already much worked in by veteran investigators.

A sojourn in Canada called his attention to the damage accruing to an apparently sound potato crop after storage, and usually attributed to the spread of the blight from tuber to tuber. It was shown that this infection was contracted during digging, chiefly from the remains of the foliage and from contaminated soil, in which it was found that the fungus survived some weeks, and a simple way of avoiding the loss was evolved which proved highly successful in practice. The field work later led to a technical study of the conidia of *Phytophthora infestans* and their power of survival in nature.

Murphy's work on virus diseases also calls for special attention. He was among the earliest students of these maladies, and the first to point out the gravity of the losses occasioned in the potato crop by "mosaic" in 1917. In a series of publications he has taken a prominent part in showing that the long-known phenomena associated with the degeneration of seed-potatoes, change of "seed," and the deterioration of potato varieties are to be ascribed to the effects of accumulating infectious diseases of the virus type, and not to climate, asexual propagation, or other similar factors. This view is now generally accepted, a fact which has led to a measure of rationalisation of the very large commerce in seed-potatoes throughout the world. Murphy was also the first to bring to light the complex nature of the disease usually known as mosaic, and he showed it to be in reality a series of diseases due to distinct viruses. The occurrence of a multiplicity of virus diseases is now recognised, not only in the potato, but in a number of other plants, and at the present day the separation

* The Medal was awarded by the Council of the Royal Dublin Society on December 15, 1932, and was presented to Professor Murphy at a Special Scientific Meeting on May 5, 1933, by Rt. Hon. Viscount Powerscourt, K.P., President of the Society.

and description of the constituent viruses of a complex is one of the most important branches of virus work. This, in Murphy's hands, has led to interesting discoveries, which have a bearing on the fundamental question of the nature and transmission of viruses, as well as on practical applications in agriculture.

The onion mildew and its cause, *Peronospora Schleideni,* has also been a subject of investigation by Murphy, and he has for the first time worked out fully the life-history of the parasite and placed its control on a sure basis. His results in this field have been recently confirmed in Japan and Russia.

Among other researches may be mentioned a study of *Phoma Lingam,* the cause of dry rot in swede turnips, in which it was shown that other reputed causes had no part in this disease.

LIST OF ACADEMIC PUBLICATIONS.

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5. Murphy, Paul A.—The mosaic disease of potatoes. Agric. Gaz. of Canada, 1917.
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19. Murphy, Paul A., and McKay, Robert.—Further experiments on the sources and development of blight infection in potato tubers. *Ibid.*, 1925.
20. Murphy, Paul A., and McKay, Robert.—Methods for investigating the virus diseases of the potato and some results obtained by their use. Sc. Proc. R. Dublin Soc., 1926.
21. Murphy, Paul A., and McKay, Robert.—The downy mildew of onions (*Peronospora Schleideni*), with particular reference to the hibernation of the parasite. Sc. Proc. R. Dublin Soc., 1926.
22. Murphy, Paul A.—The production of the resting-spores of *Phytophthora infestans* on potato tubers. Sc. Proc. R. Dublin Soc., 1927.
23. Murphy, Paul A., and McKay, Robert.—Some further cases of the production of diseased shoots by potato tubers attacked by *Phytophthora infestans*, and a demonstration of alternative sources of foliage and tuber infection. Sc. Proc. R. Dublin Soc., 1927.
24. Murphy, Paul A.—The connexion between dry rot of swedes in New Zealand and British seed. Nature, 1928.
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27. Murphy, Paul A.—Experiments on the control of American Gooseberry Mildew (1925–1929). *Ibid.*, 1930.
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31. Murphy, Paul A., and McKay, Robert.—The compound nature of crinkle, and its production by means of a mixture of viruses. Sc. Proc. R. Dublin Soc., 1932.
32. Murphy, Paul A., and McKay, Robert.—Further observations and experiments on the origin and control of onion mildew. Journ. Dept. of Agric., Irish Free State, 1932.
33. Murphy, Paul A., and McKay, Robert.—A comparison of some European and American virus diseases of the potato. Sc. Proc. R. Dublin Soc., 1932.

No. 38.

REPORT OF THE IRISH RADIUM COMMITTEE FOR THE YEAR 1932.

[Read APRIL 25. Published separately JULY 3, 1933.]

342 BATCHES of radon tubes were issued during the year for therapeutic purposes, as compared with 332 batches in 1931. The present tendency to use weaker doses has, however, reduced the total quantity of radon issued from 16,756 millicuries in 1931 to 14,820 millicuries in 1932.

Mr. P. J. Flynn and Miss M. Scott were appointed to the Radium Exhibitions falling vacant during the year.

Reports from some of the largest users of radon supplied by the Institute are printed below.

REPORT BY OLIVER CHANCE, M.B., B.CH., D.M.R.E.,

Richmond, Sir Patrick Dun's, Dr. Steevens', and Coombe Hospitals.

List of Cases Treated with Radon.

Malignant, 171.

Rodent Ulcer	48	Carcinoma Ovaries	2
Carcinoma Skin	17	„ Vulva	2
„ Lip	18	„ Breast	3
„ Tongue	22	„ Anus	2
„ Cheek	3	„ Colon	1
„ Gum	5	„ Thyroid	2
„ Palate	6	„ Penis	1
„ Floor of Mouth ...	7	Branchial Carcinoma ...	2
„ Fauces, Tonsil, and Pharynx ...	8	Brain Tumours	2
„ Cervix Uteri ...	14	Parotid Tumours	4
„ Corpus Uteri ...	1	Sarcoma	1

Non-Malignant, 43.

Tubercular Peritonitis ...	11	Lupus	5
Exophthalmic Goitre	6	Keloids	3
Fibrosis Uteri	3	Naevi	11
Menorrhagia	2	Warts	2

In an agricultural country it is difficult, even under favourable conditions, to enforce regular hospital attendance on patients who have been given radiological treatment. The present general depression has made it almost impossible. This difficulty is reflected in the poor results obtained during the last year. For example, all cases of buccal cancer left hospital after the primary growth had been treated, and were asked to return eight weeks later. Few of them did so, and many did not attend until several months later, when they were in a condition of advanced disease. It is hard to see how this hopeless state of affairs can be avoided; for the accommodation available does not permit the treatment of both primary growth and glandular field during a single stay in hospital.

Notes on Technique.

Few changes have been made in technique during the last year.

Carcinoma of Cervix Uteri.—The implantation method hitherto used in these cases has been replaced by a surface technique. Enough time has not elapsed to compare the two, but so far there is little difference between the immediate results obtained by them.

Carcinoma Mammae.—The combination of deep X-ray therapy and surgery is proving satisfactory. Radium is rarely used except when dealing with recurrences in the skin, and where operation is contra-indicated, or refused.

Carcinoma of Rectum.—The radiological treatment of rectal cancer has been very disappointing, and has now been abandoned. No case has been cured; in addition, recovery after irradiation is so slow that beds are occupied for long periods, and the treatment of more promising types of cases unduly delayed.

Graves' Disease.—In severe or acute cases a radium "collar" is preferred to X-ray therapy. It gives definitely better results, but for economic reasons is rarely used more than twice. If further irradiation is needed, X-rays are used.

Two rather unusual cases of multiple malignant disease occurring in the same individual were seen during the year. One patient had a carcinoma on the lower lip close to the right inter-labial angle, another in the upper lip close to the left inter-labial angle, and a third in the skin immediately below the left eye. All three growths were early, and all have disappeared as the result of treatment. The second case was a similar one. A cancer of the lip was excised 6 years ago. 3 years later the rectum was removed, and a permanent colostomy made. 12 months ago a carcinoma of the floor of the mouth was successfully treated by radium implantation. The patient works hard as a road-mender.

Malignant Cases.

Rodent Ulcers, 48.

Well, 41. Unimproved, 2. Untraced, 4. Dead, 1.

Carcinoma Skin, 17.

Well, 12. Unimproved, 3. Untraced, 1. Dead, 1.

Buccal Carcinoma, 69.

Total number of cases seen, 107. Treated, 69. Unsuitable, 38.

	No. of cases.	Well.	Primary well, but glands involved.	Unimpr.	Untraced.	Dead.
Carcinoma Lip, 18.						
No gland involvement ...	11	7	1	—	3	—
Glands enlarged but mobile	4	2	—	—	1	1
Glands enlarged and inoperable	3	—	1	1	—	1
Carcinoma Tongue, 22.						
No gland involvement ...	13	5	4	1	1	2
Glands enlarged but mobile	7	2	3	1	—	1
Glands enlarged and inoperable	2	—	—	1	1	—
Carcinoma Cheek, 3.						
No gland involvement ...	3	2	1	—	—	—
Carcinoma Gum, 5.						
No gland involvement ...	5	2	1	2	—	—
Carcinoma Palate, 6.						
No gland involvement ...	5	3	1	1	—	—
Glands enlarged but mobile	1	—	—	—	—	1
Carcinoma Floor of Mouth, 7.						
No gland involvement ...	5	3	1	1	—	—
Glands enlarged but mobile	2	1	—	—	—	1
Carcinoma Fauces, Tonsil, Pharynx, 8.						
No gland involvement ...	3	2	—	1	—	—
Glands enlarged but mobile	4	1	—	—	1	2
Glands enlarged and inoperable	1	—	1	—	—	—

Carcinoma Cervix Uteri, 14.

Number of cases seen, 19. Operable, 5. Border-line, 3. Inoperable, 6. Hopeless, 5.

	Duration of Symptoms.	Section.	Condition in March, 1933.
Operable, 5.			
Mrs. B., 52 years ...	4 months	+	Well.
Mrs. D., 32 years ...	2 years	+	Secondary deposits in liver.
Mrs. L., 56 years ...	1 year	—	Refused treatment.
Mrs. W., 68 years ...	5 months	—	No symptoms, but pelvic involvement.
Mrs. R., 48 years ...	5 „	—	Well.
Border-line, 3.			
Mrs. B., 32 years ...	4 „	+	Dead.
Mrs. C., 59 years ...	6 „	—	Well.
Mrs. M., 57 years ...	12 „	+	Well.
Inoperable, 6.			
Mrs. S., 48 years ...	6 „		Well.
Mrs. K., 60 years ...	12 „	—	Untraced.
Miss M., 28 years ...	12 „		Dead.
Mrs. G., 66 years ...	4 „		Well.
Mrs. J., 40 years ...	14 „	—	General carcinomatosis.
Mrs. S., 52 years ...	12 „	—	Untraced.

The question of operability was decided by the referring gynæcologist, who also made the biopsy in the cases in which this was done.

Carcinoma of Corpus Uteri, 1.

One case of recurrence in the vaginal vault 12 months after operation was treated by implantation; the patient has since died.

Carcinoma Ovaries, 2.

Unimproved, 1. Dead, 1.

Carcinoma Vulva, 2.

Well, 1. Untraced, 1.

Carcinoma Breast, 3.

No evidence of disease, 2. Improved, 1.

Carcinoma Anus, 2.

Well, 1. Improved, 1. Treatment was by colostomy and implantation of radium.

Carcinoma Colon, 1.

This patient had a tumour of the descending colon excised 3 years ago, and an end-to-side anastimosis of the bowel done after a preliminary colostomy. 2½ years later the patient attended with a tumour the size of a tomato in the colostomy scar. This was treated first with X-rays, but scarcely responded. The patient was then operated upon, and the growth found to arise from the free end of bowel. It was excised, and radium implanted round it. There is now no evidence of growth.

Carcinoma Thyroid, 2.

Improved, 1. Dead, 1.

Carcinoma of Penis, 1.

Well, 1.

Branchial Carcinoma, 2.

Treated with radium "collars." Improved, 2.

Brain Tumours, 2.

1 case was treated by decompression and radium on a mould at a distance of 5 cm. from the skin. He died two months later. At autopsy, multiple growths of an adeno-carcinomatous nature were found in the brain. Circumstances did not permit a search for the primary, which was probably of intestinal origin.

The second patient had a hæmangio-endothelioma in the occipital region, which was removed, but soon recurred. It was again partially removed, and radium needles were buried in the remainder. It is now 6 months since the second operation, and there is no evidence that the growth has recurred.

Parotid Tumours, 4.

Carcinoma of parotid, 2. Improved, 2.
Mixed-celled tumour of parotid, 2. Well, 2.
Treatment was by excision + implantation of radium.

Sarcoma, 1.

Well, 1.

Non-Malignant Cases, 43.

Tubercular Peritonitis, 11.

Well, 8. Untraced, 1. Dead, 2.

Exophthalmic Goitre, 6.

These patients had one application of radium, followed at 3-monthly intervals by courses of X-ray therapy. 5 other cases were treated by X-rays alone. Well, 3. Improved, and still under treatment, 7. Myxodema, 1.

The last case was one of severe toxic goitre of short duration. She was given one application of radium, followed by 2 courses of X-rays. Improvement was rapid, but now a mild degree of myxodœma is present, and is easily controlled by giving small doses of thyroid extract daily.

Fibrosis Uteri, 3.

Well, 3.

Menorrhagia, 2.

Well, 2.

In one patient the disease recurred 3 months after she had been given an intra-uterine dose of 50 mc. for 22 hours. 33 per cent. U.S.D. was then given to the ovaries, and as a result the patient has remained free from symptoms.

Amenorrhœa, 2.

Well, 1. Unimproved, 1.

A stimulating dose of X-rays (15–20 per cent. U.S.D.) was given to the ovaries. In one case the menstrual periods re-appeared two months after treatment, and have remained regular for 9 months.

Lupus, 3.

Well, 1. Improved, 1. Unimproved, 1.

In the treatment of these cases a single application of screened radium is used. This is sufficient to cause desquamation of normal skin.

Keloids, 3.

Well, 1. Unimproved, 2.

Naevi, 11.

(*a*) Angiomata, 7. Well, 4. Still under treatment, 3.

(*b*) Venous Naevi, 4. Unimproved, 4.

Warts, 2.

Well, 1. Unimproved, 1.

Report by Oswald J. Murphy, M.B., B.Ch.,

St. Vincent's Hospital, Dublin.

This report, covering as it does 3 years, includes cases dealt with in my 1930 and 1931 reports to the Irish Radium Committee of the Royal Dublin Society.

Malignant Cases Treated, 319.

	Number		Died in				Known to
	Seen.	Treated.	1st year.	2nd year.	3rd year.	Untraced.	be well.
Carcinoma—							
Lip	16	15	2	4	2	4	3
Tongue	27	17	9	4	—	2	2
Palate	8	8	3	1	1	1	2
Tonsil	7	7	4	1	—	1	1
Pharynx	6	5	4	1	—	—	—
Larynx	8	7	5	2	—	—	—
Thyroid	4	4	2	1	—	1	—
Œsophagus	3	2	2	—	—	—	—
Branchial Cleft	9	8	7	—	—	—	1
Breast	14	9	2	4	—	3	1
„ Secondaries	12	12	6	2	—	3	1
Penis	2	2	1	—	—	—	—
Rectum	4	3	2	1	—	—	—
Anus	2	2	—	1	—	—	1
Uterine Cervix	15	15	4	4	—	4	3
Uterine Body	3	2	—	—	—	2	—
Skin Surfaces	83	72	5	11	1	17	31
Glands in neck	22	19	6	8	—	3	2
Glands in Axilla	8	7	3	2	—	1	1
Melanotic Sarcoma	4	4	4	—	—	—	—
Sarcoma, Maxillary Antrum	2	2	1	—	—	—	—
Rodent ulcers	97	97	—	—	—	—	91
	—	—	—	—	-	—	—
	356	319	72	47	4	42	140
	—	—	—	—	-	—	—

Non-Malignant Cases, 126.

	Number Treated.	Cured.	Improved.
Exophthalmic Goitre ...	2	—	2
Enlarged Spleen	2	—	2
Hodgkin	17	2*	14
T.B. Cervical Glands	11	2	7
Oto Sclerosis	2	—	—
Uterine Hæmorrhages	6	4	1
Angiomata	29	21	7
Granuloma Annulare	3	3	—
Lichen Planus	1	—	—
Lupus Vulgaris	3	—	2
Lupus Erythematosus ...	1	—	1
Keloids	22	16	2
Pruritis Ani	1	—	1
Pruritis Vulvae	1	—	1
Warts	25	25	—
	—	—	—
	126	73	39
	—	—	—

* Two of the Hodgkin cases have reported free from symptoms for 18 and 16 months, respectively.

Malignant Cases Treated, 319.

In the treatment of the following cases radon alone was used:—

Carcinoma of Lip, 15.

Most of these cases presented themselves for treatment in an advanced stage of ulceration. In spite of this, it was surprising to find absence of palpable glands in many cases. Advanced dental caries and/or pyorrhea existed in every case. In treating epithelioma in this area it is necessary to irradiate a wide area beyond the primary growth.

Platinum or gold needles, ·5 mm. screening, each containing 1·6 to 2 millicuries were used. Duration of irradiation, 7–8 days.

Carcinoma of Tongue, 17.

Here, again, few cases were seen in an early stage; all had dental caries and most had pyorrhea. In several cases adequate oral toilet was impossible owing to the proximity of ulceration. Of the 17 cases, I can only claim that 2 early cases remain free from any signs of activity—the growths in these cases were on the lateral aspect of the tongue in the middle $\frac{1}{3}$. The glands were removed in some cases 6 weeks after irradiation. Removal of glands before, during, or shortly after implantation of needles tends to spread the lymphatic spread, if any, towards the unaffected side.

12 cases showed extensive gland involvement.

Carcinoma of Palate, 8. Hard Palate, 4. Soft Palate, 4.

Dental plates were used to carry the needles when treating the hard palate. In cases of the soft palate, the soft palate and the pillars of the tonsils were needled. The 2 cases at present reporting well were seen early, and, therefore, ideal cases for treatment. One was on the hard and the other on the soft palate. Duration of irradiation varied from 4–8 days.

Carcinoma of Tonsil, 7. *Pharynx,* 5. *Larynx,* 7. *Œsophagus,* 2.

The only satisfactory results under the above headings were one tonsil and one pharyngeal case. In the tonsil case the tonsil was removed and the base needled. Duration of irradiation, 3·85 days, each needle containing 2·5 millicuries.

In the pharyngeal case the ulcer healed, but the patient died from heart disease after 8 months.

Carcinoma of Thyroid, 4.

Surface application from a distance of 3 cm., screenage 2 mm. lead, was employed in 3 cases and needling in one. The immediate effects were relief of pressure symptoms, adding greatly to the comfort and peace of mind of the patients. All were inoperable.

Carcinoma of Branchial Cleft, 8.

In all except one irradiation followed surgical removal of the growth. One case seen early operated on, and subsequently irradiated from a Radium Collar, is still alive, and shows no active signs or symptoms after 4 years.

Carcinoma of Breast, 9.

Although 14 were seen, it was only justifiable to treat 9, the others being too far advanced to offer much hope of relief. I am convinced that the time is not yet when surgery should give way to irradiation. I think a combination of the two is not only advisable but essential.

12 cases of secondary involvement of the breast area following operation were treated. These secondary nodules as a rule are radio-sensitive.

Keynes' technique, combined with exclusive surface applications, was employed.

Carcinoma of Penis, 2.

These were treated during the last year—one has died, while the other is progressing favourably. In this case the area of ulceration was very limited, and there were no palpable glands in the groin. The primary growth has disappeared, and the site is soft.

Carcinoma of Rectum, 3.

None of these was successful, although there was a considerable improvement in one patient. Cachexia disappeared, weight, appetite, and energy improved for a time; but she died in just under 2 years.

Carcinoma of Anal Orifice, 2.

Both were seen early, and the fungating area was small. The first case had also carcinoma of the rectum. Heavy dosage over short periods completely cleared up both growths, and one case has had no further trouble. One case was needled (the second), the other had surface irradiation.

Carcinoma of Uterine Cervix, 15.

The technique originally consisted of intra-uterine irradiation—2 tubes in tandem, screened by 2 mm. lead enclosed in a gum elastic catheter. This was left in position for from 7–8 days, the dosage varying from 2,400–3,000 milli-curie-hours.

Vaginally around the cervix tubes (lead) were placed in a hard paraffin wax, moulded accurately to fit the cervix and diseased area; later a central tube for uterine drainage, etc., was incorporated.

During the last 2 years I have discarded the wax mould, and I now resort to needle implantation into growth, cervix, and fornices.

Four inoperable cases, in 2 of which the rectal wall was involved, died in the first year and 4 in the second. 7 remained free of symptoms for nearly 2 years, and since then I have lost trace of 4 more. The remaining 3 are perfectly well at present.

Carcinoma of Uterine Body, 2.

Both were early cases, but neither has reported since treatment.

Carcinoma of the Skin, 72.

Many of these were small epitheliomata seen at a very early stage in the Out-patient Department in the Hospital. Many were elderly and decrepit. Although 17 died in the 3 years, by no means did all die of the malignant trouble. The majority received surface applications, but where necessary needling was resorted to. Beta, combined with prolonged gamma, radiations were usually employed.

Secondary Carcinomatous Glands in the Neck, 19.

All were secondary to carcinoma in the buccal cavity except 6, which were due to divers epitheliomata on the face or lip. Both plaques and needles were used—plaques for palliative measures only. Only 2 of the 19 report themselves as "cured." These secondaries are obviously radio-resistant, and very difficult to deal with except by surgical means.

Secondary Carcinomatous Glands in the Axilla, 7.

Secondaries, to breast carcinoma, in the axilla are not so insensitive to radium treatment as are secondaries in the neck, but the trouble is that by the time the axillary glands are first noticed by the patient the disease has progressed beyond our reach.

Melanotic Sarcoma, 4.

No treatment was of any avail. Irradiation followed surgical removal, and the area irradiated extended far beyond site of primary growth. Two growths were on the back, one in the groin, and one on the forearm.

Sarcoma of Maxillary Antrum, 2.

One, treated by a heavy dose over 3·5 days, died in 2 months. The second has only been treated 5 months ago—the patient is a young girl of 14.

Rodent Ulcers, 97.

The only cases presenting any difficulty were those involving the inner canthus of the eye and 3 cases which did not respond to treatment.

Beta irradiation, needling, where necessary, and surface applications were employed. I usually employ plaques—they are—all other factors being equal—preferred by the patients.

Report by John A. Geraghty, M.B.,

Mater Misericordiae Hospital.

Cases of Malignant Disease treated with Radon supplied by the Royal Dublin Society.

(1) 7/1/'32.—*Female, aged 45 years.*

Colostomy one year ago for inoperable carcinoma of rectum. Extensive ulceration and stenosis of rectum with involvement of anus now present. Treatment—(*a*) Deep therapy to pelvis, followed by (*b*) tubular radon applicator in rectum. Filter 3·0 mm. lead and 3·0 mm. rubber. 3,852 mc.-hours in 5 days. Two months later, felt much better and had less pain. One month later, 10 platinum needles (0·3 mm.) implanted in anal growth. 3,458 mc.-hours in 4 days. Two months later, reported feeling comfortable, and anal growth had disappeared. Six months later, died.

(2) 6/2/'32.—*Male, aged 75 years.*

Recurrent epithelioma angle of mouth. Implantation of platinum needles (0·3 mm.) 1,680 mc.-hours in 6 days; followed by deep therapy to associated lymphatics. Discharged much improved. 15/7/'32.—Recurrence in lower lip with enlargement of submental glands; 14,000 mc.-hours in 11 days. Distance 3 cm. Filter 3·0 mm. lead. Temporary improvement followed. Five months later, died.

(3) 6/4/'32.—*Male, aged* 73 *years.*

Rodent near ear. Deep therapy. Healed. Recurrence on ear 6 months later. Excised. 1,396 mc.-hours in 5 days by implantation in surrounding tissue. Filter 0·3 mm. platinum. Healed within two months.

(4) 28/4/'32.—*Male, aged* 75 *years.*

Rodent on nose. Deep therapy. Much smaller ten weeks later. 31·5 mc.-hours; 0·1 mm. lead. Completely healed six weeks later.

(5) 11/7/'32.—*Male, aged* 53 *years.*

Tumour right side of neck; ? branchial. Deep therapy. Four months later a little thickening still present. 930 mc.-hours in 5 days by implantation of 0·3 mm. platinum needles. To report in two months.

(6) 6/10/'32.—*Female, aged* 35 *years.*

Rodent on nose. 45 mc.-hours on surface with 0·1 mm. lead filter. Healed in six weeks.

(7) 28/9/'32.

Epithelioma size of palm of hand rapidly spreading on old lupus scar on cheek. Implantation of platinum needles (0·3 mm.) 3,928 mc.-hours in 9 days. Two months later much improved. 1,662 mc.-hours in 7 days. Three months later ulcer much smaller but associated lymphatic glands enlarged. Further treatment not advised.

(8) 17/10/'32.—*Male, aged* 55 *years.*

Epithelioma of nose. Deep therapy; little improvement. Mould 2 cm. thick around nose. Filter 3·0 mm. lead. 7,491 mc.-hours in 1 month. One month later, healed.

(9) 14/12/'32.—*Male, aged* 60 *years.*

Rodent on nose. Excised, leaving an area the size of florin. Flat applicator with 0·1 mm. lead filter. 60 mc.-hours in 4 fractions on successive days. Healed two months later.

No. 39.

A NEW SILVER FILTER FOR ULTRA-VIOLET LIGHT.

By G. C. Brock, B.Sc.

[Communicated by Dr. J. H. J. Poole.]

[Read January 24. Published separately June 26, 1933.]

In the course of some work on the photography of old manuscripts by the fluorescent light method, the need of a suitable filter for the 313$\mu\mu$ line of the mercury arc was encountered. Silver films, deposited chemically, or by cathode sputtering, on plates of quartz or thin "uviol" glass are commonly used for this purpose. An ideal filter would be opaque to all wave-lengths except 313$\mu\mu$, while one which was nearly opaque to visible light, and transmitted, say, 50 per cent. at 313$\mu\mu$, would be of practical use. Silver filters, however, do not approach even this lower standard of efficiency.

The silver films referred to in this note were deposited by cathode sputtering, but no doubt the optical properties of chemically-deposited films are similar, as in each case the appearance resembles that of the polished metal. The reflecting power of silver falls off to a very low value in the neighbourhood of 313$\mu\mu$, hence a thin film of the metal acts as a filter for light of that wave-length, the efficiency depending on the relative absorption at the different wave-lengths.

It is found in practice that the ultra-violet light transmitted by a silver filter is greatly reduced in intensity unless the film is made so thin that a high proportion of visible light is also passed. The filter is, therefore, of little use, in conjunction with the mercury arc, for the observation of feeble fluorescent effects. If we adjust the thickness of the film so that only 20 per cent. of the incident 313$\mu\mu$ radiation is transmitted, the feeble fluorescence which this excites in such substances as parchment is hidden by the blue and violet light simultaneously passed by the filter. When engaged in the photography of fluorescences we are even in a worse case; for the blue and violet mercury light, though relatively dark to the eye, is highly actinic. In this case improvements can be attempted in two ways. We can use a thicker silver film, or, better, two thin films, to improve the sharpness of the cut-off. A limit is soon reached, however; for a filter passing less than 1 per cent. of the 313$\mu\mu$ line still transmits enough of the blue and violet light to mask the fluorescence. By using on the camera lens a green or yellow light filter we can reduce the effect of the unwanted blue and violet radiation, at the same time slightly weakening the fluorescent light reaching the plate. Here again the practical limit of the method is reached before any useful progress has been made.

In these circumstances there is a need for a filter having a high absorption in the blue-violet, while passing the 313$\mu\mu$ line freely. Relatively good transmission in the red does not matter if a mercury arc is used. According to Peskov (1), such a filter is provided by a colloidal solution of silver.

As a preliminary experiment, a colloidal silver solution was prepared by Bredig's method, and the brown colour at once recalled that of the warm-toned lantern slides familiar to photographers. The colour of such lantern slides, and of others ranging in colour from red to blue, has been attributed to the presence of colloidal silver particles of different sizes (2). This view, therefore, suggested that a lantern emulsion developed to a warm tone and stripped from the glass might provide a useful filter. Such films were in fact found to be superior to sputtered silver filters, as an examination of the absorption curves will show. Silver in the normal (black) photographic state does not seem to be transparent to the 313$\mu\mu$ line.

Preparation of Filters.

The lantern plate is exposed (taking care that it is evenly illuminated), and developed, fixed, and washed, as usual. The problem of obtaining a silver deposit of the required colour and density is essentially the same as that met with in the ordinary production of lantern slides, and is dealt with in photographic literature. Generally speaking, length of exposure governs density, while length of development controls colour, shorter development producing warmer tones (*i.e.*, redder browns). Very short development times do not give sufficient density, no matter how long the exposure may have been. For very warm browns, verging on red, the exposure must be greatly increased, and development carried out in a highly restrained solution. The exposure and development should be so arranged that the plate reaches the desired colour and density at the same time. Since, however, the colour of the deposit is not critical, it is usually sufficient to determine this roughly by using a suitable developer, and to aim at correct density only.

A pyro-soda developer (3) was used for the production of brown deposits. By increasing the exposure and the amount of restrainer (KBr) colours approaching red are obtainable, but these films are less efficient as filters. Although exact details must be arranged to suit individual needs, an example is given to indicate the order of exposure, &c. A "Gravura" plate, exposed for 2 minutes at 8 inches from a 60 watt "Pearl" bulb, and developed for 7 minutes at 70° F. in the pyro solution (Pyro soln. 15 c.c., Carbonate soln. 15 c.c., 10 per cent. KBr soln. 10 c.c.) gave a deposit of suitable density.

A Metol-Hydroquinone developer, restrained with ammonium bromide and "ammonium carbonate," also gave good results.

Blue filters were prepared by using Mees' thiocarbamide formula (4). Accurate control of the time and temperature of development is desirable in all cases, and especially necessary when using thiocarbamide solutions, as the colour change is very rapid. Reference may be made to the photographic

literature for further details of this process (4), (5), but as the blue filters are inferior to the brown it is not of great importance.

The developer should always be kept well agitated, and no attempt made to judge the colour or density of the plate until it is dry.

Sterry's method (6) was used for stripping the gelatine films from the glass when finished. The stripped films were always found to be coated with a greasy scum, which necessitated further washing. This additional wetting and drying increases the density of the deposit, and this must be allowed for in the earlier stages. The finished filter may be protected from damage by clipping it between two sheets of Vita-glass, which is transparent to 313$\mu\mu$ radiation.

Wellington "S.C.P.," Paget Gravura, and Criterion "Mezzotone" plates were used, but no doubt any chloride or chloro-bromide plate would be suitable. Bromide emulsions do not give brown tones so easily.

One advantage of this method of preparing silver filters is that lantern-plate emulsions are coated on glass of all sizes for commercial use, so that large filters can be easily and cheaply made. The chief difficulty and risk are associated with the stripping process, but these troubles can be overcome by systematic working. It might be possible to obtain the emulsion coated on to "uviol" glass or "Vita-glass," which would obviate the need for stripping.

Absorption Measurements.

The absorption of the filters was measured with the aid of a Hilger Quartz spectrograph, using as source a Hanovia "Homesun" mercury arc. When exposing through the filters, the lamp was moved closer to the spectrograph in order to reduce the time of exposure, the equivalent exposures being calculated from the inverse square law. The arc is not a point source, being about 5 cm. in length, but as it was never closer than 1 ft. to the slit, no great error was introduced by using the law.

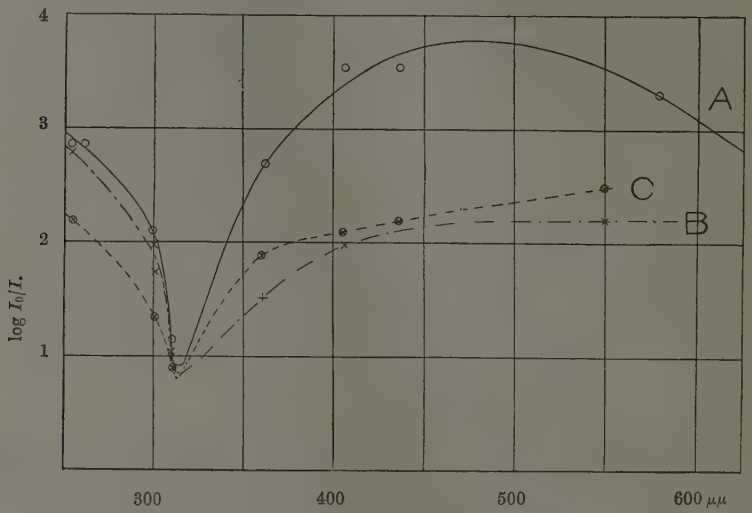
A series of equal exposures was made leaving blank alternate spaces on the plate; then a series of increasing exposures, using these spaces, the filter now being between the slit and the arc. Let E_1, d_1 be the duration of exposure and distance of the lamp respectively for the first exposure, and E_2, d_2 corresponding values for that exposure of the second series, which produced equal blackening on the plate for a particular line. Then the absorption of light at that wavelength is given by the relation

$$\frac{I}{I_0} = \left(\frac{E_1}{E_2}\right)^p \times \frac{d_2^2}{d_1^2}$$

where I_0 and I are the intensities of the incident and transmitted light respectively. The Schwarzchild constant 'p' was taken as 0·86. From the fraction $\frac{I}{I_0}$ the percentage transmission 'T' and the absorption factor, $\log_{10} \frac{I_0}{I} = 2 - \log_{10} T$, were obtained. Further details of the method are

given in the literature, *e.g.*, in Peskov's paper (1). The values obtained for $\log \frac{I_0}{I}$ are shown in the figure.

The plates were developed in the ordinary way, and the equality of density of the lines was judged by eye. The accuracy obtainable by this procedure is quite sufficient for demonstrating the relatively great differences between the various types of filters.



Curve A. Red-brown lantern plate film.
Curve B. Sputtered silver filter.
Curve C. Blue lantern plate film.

Summary.

A method is described for the preparation of a filter for the 313$\mu\mu$ line of the mercury spectrum from a photographic lantern plate. This filter is superior to the silver films commonly used to isolate the same line. The filtering action is attributed to the presence of colloidal silver, and this, deposited in particles of different sizes, gives rise to filters of different colours, all showing a maximum of transmission near 300$\mu\mu$. Reddish brown filters, having a high absorption in the blue-violet, are the most useful, especially for work involving the photography of fluorescences.

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No. 40.

A STUDY OF THE CRINKLE DISEASE OF POTATOES AND OF ITS CONSTITUENT OR ASSOCIATED VIRUSES.

By PHYLLIS CLINCH, M.Sc., Ph.D.,

AND

J. B. LOUGHNANE, B.Agr.Sc.,

Albert Agricultural College, Glasnevin, Dublin.

[Read April 25. Published separately September 15, 1933.]

(Plates 48, 49.)

Introduction.

The present work deals with cross inoculation studies and the problem of insect transmission of certain virus diseases of the potato belonging to the mosaic group, notably the crinkle complex and its constituents simple mosaic (or interveinal mosaic) and virus A. Murphy and McKay (13), (15) have shown that when virus A, which was found occurring naturally in comparatively normal plants of Irish Chieftain, was combined with simple mosaic, typical crinkle resulted; while the combination of interveinal mosaic and virus A also produced a crinkle but with slightly different characteristics. The same authors showed that a virus present in Up-to-Date which is a carrier of streak (acronecrosis) could also combine with virus A to produce a type of crinkle, and this streak has therefore been included in the study.

One of the objects aimed at in the investigation has been to relate the work to that of others in the same field. Salaman (20) working with crinkle observed that while grafting transmitted the disease in full from potato to potato, needle inoculation produced under the same circumstances a mild mosaic. This result was at first explained on the assumption that the crinkle virus had been attenuated, and the mild mosaic was therefore called "reduced crinkle," but later Salaman (22) concluded that the change was due to the splitting of the crinkle complex, the "reduced crinkle" being one constituent, and the other a virus named *Z* derived from paracrinkle. K. M. Smith (24), (27), (28) in a series of papers presented evidence to show that Arran Victory mosaic, crinkle in Myatt's Ashleaf, streak carried by Up-to-Date, and many other virus diseases of the potato, contained at least two constituents termed *X* and *Y*, both of which were transmitted by needle, while *Y* alone was selectively transmitted by the aphis *Myzus persicae*. These important results have been discussed by Murphy (14). In the present work viruses showing a greater or less similarity

to the *X* and *Y* of Smith have been met with, and their relationship to the latter is discussed. The diseases actually dealt with are defined as follows:—

Simple mosaic causes a mild, diffuse, irregularly distributed mottle in the foliage of President and Arran Victory without accompanying tuber lesions. The disease occurred originally in Arran Victory but it appears to be milder than the Arran Victory mosaic referred to by Smith (24), (27). It is the same as that used by Murphy and McKay (13), (15) in their experiments.

Crinkle.—This disease, as it occurs in President, Arran Victory, Irish Chieftain and certain other varieties is generally well known, and has been fully described by Murphy (10), Quanjer (16), and Salaman (20), who refers to it as crinkle A in order to distinguish it from paracrinkle. When crinkle in the above mentioned varieties is transferred by grafting to healthy plants of the same varieties an exactly similar disease is produced in the stock plants.

Virus A disease.—Virus A occurs naturally in the variety Irish Chieftain in which it is carried almost without symptoms, the only evidence of infection being vein-clearing and a light transient mottle, without tuber lesions.

Interveinal mosaic appears as a pronounced interveinal mottle in President, Arran Victory and certain other varieties, accompanied by some rusty necrotic patches on the leaves. The disease causes characteristic lesions in the tubers of President, which are described elsewhere in this paper.

Streak.—This disease, present in the majority of Up-to-Date plants, is well known. It is practically carried by Up-to-Date which at times, however, may look slightly mottled. When scions of Up-to-Date carrying streak are grafted on President and Arran Victory, a violent acronecrosis is produced in the stock plants. The tubers of such plants are also severely affected by necrosis which destroys the vascular and other tissues in the manner described by Bawden (1). Murphy and McKay (15) inclined to the opinion that the streak in Up-to-Date is accompanied by a mild mosaic similar to simple mosaic. This question will be discussed later.

Simple Mosaic.

Reactions of simple mosaic in various hosts.

Nicotiana Tabacum (**Tobacco**), White Burley variety:—On inoculation of simple mosaic in President or Arran Victory to tobacco, local symptoms usually appeared on the inoculated leaves at the end of 10 days, consisting of vague chlorotic rings or spots. General symptoms were often slow to develop and slight in nature, and included pale areas spreading from the veins, and nebulous chlorotic markings in the interveinal areas, some of which took the form of rings, accompanied occasionally by a few whitish, almost necrotic spots. The symptoms were of a similar nature to, but definitely milder than, those secured by K. M. Smith with his Arran Victory mosaic (24).

Needle inoculations were made from tobacco infected with simple mosaic to 8 young healthy President and 2 Arran Victory plants. Symptoms appeared

in about 16 days, consisting of a very mild mottle, more pronounced in the lower leaves, together with a few necrotic specks. The symptoms corresponded to those of the original simple mosaic, and they were reproduced when the tubers were grown in the following season.

Datura Stramonium.—Simple mosaic was found to be readily inoculable by needle to *Datura*, symptoms appearing after 9–14 days. Sometimes a few small rings developed on the inoculated leaves but the most consistent early symptom was a clearing of the veins of the leaves above the inoculated ones, accompanied by a certain number of chlorotic spots which sometimes became necrotic. Later the symptoms faded somewhat, and the leaves became mildly chlorotic all over except for dark green areas in the region of the veins. The symptoms were milder than those caused by crinkle and interveinal mosaic in *Datura*.

When scions of *Datura* infected with simple mosaic were grafted on healthy President, the stock plants developed a mild mottle, accompanied by a few necrotic specks, which corresponded to the symptoms of the original simple mosaic.

Solanum Dulcamara.—On inoculation of simple mosaic into 4 plants of *S. Dulcamara*, very slight vein-clearing appeared after 14 days, and later an extremely mild mottle accompanied by some wrinkling of the leaves and a tendency for the green colour to deepen in the region of the veins. As the plants grew older these symptoms disappeared, and the foliage became normal. A similar fading of symptoms was observed by K. M. Smith (28) on inoculation of the *X* virus to this host.

The disease was not returned to potato in this case.

Petunia (garden variety).—Four *Petunia* plants were inoculated with simple mosaic *ex* President. The plants displayed a mottle which, however, was apparently not a disease symptom, for on inoculating back to tobacco no symptoms developed on the latter. All the *Petunia* plants grown in the greenhouse during that season, whether inoculated or not, displayed a variable yellowish interveinal mottle which was sometimes intense and sometimes mild. The presence of this mottle, with the consequent concentration of the chlorophyll in the region of the veins, gave an appearance of vein-banding. Numerous inoculations from these plants to tobacco proved negative, and it was concluded that the appearance was not due to a transmissible disease.

Attempted insect transmission of simple mosaic.

Attempts were made to inoculate simple mosaic into tobacco (var. White Burley) by means of *Myzus persicae*. In 1932 29 tobacco plants were used, 4 of which were colonised with aphides from simple mosaic in Arran Victory, and the remaining 25 with aphides from simple mosaic in President. The aphides were reared on the sources and were allowed to feed on the tobacco plants for a minimum period of 7 days. No disease symptoms whatever developed in any

of the tobacco plants, and needle inoculation from them to healthy potatoes (President and Arran Victory) also gave negative results.

In 1933 a similar experiment gave negative results. Six tobacco plants were used, the source of disease being simple mosaic in President. An attempt in 1932 to inoculate simple mosaic into *Datura Stramonium* by means of *Myzus persicae* proved negative.

Crinkle.

Reactions of crinkle in various hosts.

Potato (var. President).—When crinkle was graft-transmitted from President or Irish Chieftain to healthy President plants, the latter developed the full symptoms of the original crinkle as described by Murphy and McKay (15) and Salaman (20), and these symptoms were maintained in the succeeding tuber generation.

Needle inoculation of crinkle in President to healthy President plants resulted in the production of a simple mosaic mottle accompanied by necrotic specks (Fig. 3) (Cf. Salaman (20)). The full crinkle disease was not transmitted. The tubers of these plants when grown in the succeeding year produced plants in turn which showed the same mild mottle. This needle-transmitted disease resembled simple mosaic except that it was more pronounced in its symptoms, especially in the early stages, although the two were almost indistinguishable later. Salaman (20) referred to the corresponding disease secured in his experiments as "reduced crinkle." This term had its origin in the supposition that the disease was "essentially the same as that in President crinkle A itself" although in a reduced condition, but since it has been shown by Murphy (14), and by Salaman (22) himself, that this view is untenable, it is preferable that it should not be used. For the sake of brevity and for the purpose of the present paper the disease is referred to as "Mosaic *ex* C." It has been found that the reactions which it produces in solanaceous hosts differ from those of simple mosaic only in intensity.

A significant difference between crinkle and mosaic *ex* C was observed when the two were *grafted* on the varieties British Queen and Up-to-Date. Crinkle caused in both a severe necrotic disease which usually killed the plants (Cf. Murphy and McKay (15)). Mosaic *ex* C, on the other hand, produced a mosaic mottle without necrotic lesions.

It will be shown in a later section that the other virus constituent of crinkle, namely virus A, is dropped on needle transmission. When a re-combination was made by core-grafting Irish Chieftain carrying virus A into President infected with mosaic *ex* C, typical crinkle again resulted.

Tobacco (var. White Burley). About 30 inoculations from crinkle in President and 10 from crinkle in Irish Chieftain were made to healthy tobacco seedlings, infection being secured in every case. Control plants, inoculated from healthy President, remained normal.

Symptoms develop 7 to 9 days after inoculation in the form of concentric rings on the inoculated leaves and vein-clearing in the leaves above these. The vein-clearing is soon accompanied by a mottle and gradually the leaves are covered by a pattern of chlorotic markings, many of them ring-shaped, and numerous pale spots which frequently become necrotic. As a new leaf develops the symptoms appear first at the tip and then spread over the entire lamina. When the leaves get old they are almost completely chlorotic except for bands of dark green colour bordering the main veins.

Needle inoculations were made from these tobaccos to 8 healthy President and 2 healthy Arran Victory plants. Symptoms appeared on an average about 18 days after inoculation. The plants displayed only a simple mosaic mottle, accompanied sometimes by occasional necrotic specks, and resembling mosaic *ex* C. These symptoms persisted during the growing season, and reappeared in the succeeding year. In no case has crinkle been recovered in full by needling to potato from tobacco needle-inoculated with the disease. It was found, however, that the mosaic obtained on passing crinkle by needle through tobacco to potato gave rise, when grafted with Irish Chieftain containing Virus A, to crinkle exactly similar to the original disease.

Nicandra physaloides.—On needle-inoculating crinkle in President to *Nicandra physaloides* the latter developed symptoms after 10–12 days. Dark red necrotic specks appeared on the inoculated leaves in the vicinity of the needle scratches while the leaves above these showed vein-clearing. Following this, irregular chlorotic patches spread outwards from the veins, accompanied in the interveinal areas by yellow spots, which eventually became necrotic. Six President plants were grafted with scions from these infected plants of *Nicandra physaloides*. In 18–21 days the young side shoots of the stock plants showed a distinct mosaic mottle accompanied by a few small necrotic specks. No crinkle symptoms were produced in the year of grafting, nor in the following season. This mosaic, when core-grafted with Irish Chieftain carrying virus A, gave typical crinkle. It thus resembled mosaic *ex* C (obtained by needling crinkle from potato to potato) as well as the mosaic recovered on potato from tobacco which had been needle-inoculated with crinkle.

Datura Stramonium.—Crinkle readily caused infection when needle inoculated to *Datura Stramonium* and symptoms developed regularly after 7–9 days. These consisted of vein-clearing in the leaves above the inoculated ones accompanied by pale spotting in the interveinal areas. Usually, some of these spots turned brown and occasionally many of the finer veins became necrotic also, giving the leaf a rusty appearance. With the subsequent growth of the plant, the symptoms became less intense, and ultimately always consisted of a gradual chlorosis of the interveinal areas, resulting in the restriction of the dark green colour to the neighbourhood of the main veins, as described by Salaman (20).

Scions from the above *Datura* plants were grafted on 7 healthy President plants. These developed a mild mottle accompanied by a few necrotic specks,

a result in agreement with that obtained by Salaman (20), and the same mosaic reappeared when the tubers were grown in the following year. Four more healthy Presidents were grafted with similar *Datura* scions and also with scions of Irish Chieftain carrying virus A. The basal stocks in this case developed in the current year a yellowish mosaic mottle without crinkling, but in the following year the resulting plants showed typical crinkle.

It is evident, therefore, that passage of crinkle by needle inoculation through *Datura Stramonium* results in the removal of a constituent from the crinkle complex, leaving a mosaic apparently identical with mosaic *ex* C. Like the latter, this residual mosaic produced only a mottle without necrotic lesions when introduced into British Queen and Up-to-Date potato by core-grafts.

Capsicum annuum.—Six plants were needle inoculated with crinkle *ex* President, and 3 plants with crinkle *ex* Irish Chieftain. Symptoms appeared after about 14 days and took the form of a mottle, which increased in intensity and was accompanied by severe crinkling of the leaves. The plants were very much stunted, as compared with the controls, and the symptoms, instead of becoming milder as they do in certain other hosts, increased in severity as time went on. The chlorotic areas became yellow, the foliage became very much wrinkled, and necrotic lesions also developed. Scions from the infected *Capsicum* plants when grafted on potato failed to survive.

Tomato (variety Kondine Red).—Six plants were inoculated with crinkle *ex* President. The first symptoms consisted of a vague mottle on the leaves together with a few necrotic patches on the main veins. The mottle rapidly increased in intensity and the necrosis spread to some of the finer veins. After a time the interveinal areas became light yellow, the dark green colour being confined to a narrow band along the veins. As new leaves developed they did not display such pronounced symptoms. The disease was not returned to potato.

Solanum Melongena.—Six plants were inoculated with crinkle from President, and 3 with crinkle from Irish Chieftain. The symptoms consisted of a fine mottling all over the leaves, and later of a pale banding along the veins with very dark green patches of colour in the interveinal areas. The disease was not returned to potato.

Solanum Dulcamara.—Six plants were inoculated with crinkle *ex* President. After 14 days vein-clearing began in the leaves above the inoculated ones. Following this there developed a very mild light green mottle accompanied by some puckering of the lamina, but after a time the leaves became smooth, the mottle effect disappeared and the plants looked normal. K. M. Smith (28) observed a similar fading of the symptoms when *S. Dulcamara* was inoculated with his *X* virus.

Petunia (Garden variety).—Early in 1932, five *Petunia* plants were inoculated from crinkle in President and five from crinkle in Irish Chieftain, in order to determine whether the *Y* virus formed part of the crinkle complex and, if so, to isolate it according to the method described by K. M. Smith (28).

All the *Petunia* plants, including uninoculated controls, developed the mottle referred to on p. 569, but no special symptoms of disease could be detected on the inoculated plants. Needle inoculations were then made from these *Petunia* plants to healthy tobacco seedlings with the expectation that *Y*, if present, would manifest itself with symptoms of green vein-banding. Contrary to expectation, the tobacco plants did not respond with the development of exclusive *Y* symptoms. In the case of crinkle *ex* Irish Chieftain, the tobacco plants developed concentric rings on the inoculated leaves after 8 days, followed by definite vein-clearing and the appearance of numerous well-defined concentric rings on the upper leaves. On the young growth, however, the symptoms were less intense. They would be described as those of *X*, or *X* + *Y*, in K. M. Smith's terminology. It will be seen later that passage of interveinal mosaic through *Petunia* to tobacco gave a similar result.

Crinkle *ex* President when similarly needle inoculated through *Petunia* to tobacco produced no symptoms in the latter, but this is not believed to indicate any fundamental difference between the crinkles present in that variety and in Irish Chieftain, but rather the difficulty (also experienced in the case of other potato mosaics in the present experiments) of infecting *Petunia*. On repeating the same experiment later in the season, crinkle from both varieties failed to cause infection when needle-inoculated into *Petunia*, for no disease was recovered from the latter on tobacco. In this experiment, only three *Petunia* plants were inoculated from each source of crinkle, and the conclusion has now been reached that this number is inadequate in the case of this particular host.

Reactions of mosaic ex C in various hosts.

The mosaic disease obtained by needle inoculation from crinkle-infected President to healthy President potato was inoculated into potato (var. Arran Crest), tobacco, *Datura Stramonium*, and *Petunia* with the following results:—

Potato (var. Arran Crest).—Numerous streak lesions developed on the inoculated leaves after 8 days. These rapidly became so severe that the leaves withered and dropped off, the necrosis in the meantime spreading to the main stem and growing points. In a short time the plants were killed by streak of the acronecrotic type (Cf. Salaman (20)). Murphy (14) pointed out that simple mosaic induces a similar lethal disease in Arran Crest.

Tobacco.—The symptoms produced were similar to those obtained on inoculation of crinkle to this host and were more intense than those following inoculation with simple mosaic (Fig. 8).

Datura Stramonium.—In this host mosaic *ex* C also gave rise to symptoms similar to those produced by needle inoculation with crinkle.

Scions from *Datura* plants infected with mosaic *ex* C were grafted on healthy President potato, in which they produced a mild mosaic mottle which was maintained in the following season. This mosaic disease in President resembled closely the original mosaic *ex* C. When core-grafted with Irish

Chieftain containing virus A it formed crinkle, and when grafted on healthy British Queen potato it produced a preliminary interveinal mottle (which faded later) without necrotic lesions. It also failed to produce necrotic symptoms when grafted on Up-to-date, and, when needle-inoculated into tobacco, produced symptoms which were more severe than those of standard simple mosaic and were very similar to those caused by crinkle. It is clear, therefore, that passage through *Datura* did not cause any demonstrable change in mosaic *ex* C.

Petunia.—Six plants were needle inoculated with mosaic *ex* C but failed to develop disease symptoms. After several weeks inoculations were made from these *Petunia* plants to young tobacco plants. The latter also failed to show symptoms, and it was concluded that the inoculation to *Petunia* had been unsuccessful in the first instance. Results of other experiments, however, suggest that *Petunia* is probably susceptible to mosaic *ex* C, but that it may be necessary to inoculate large numbers of plants in order to secure infection.

Attempted transmission of crinkle by insects.

These experiments were carried out in insect-proof glasshouses. Chief use was made of the aphis *Myzus persicae* Sulz. while *Macrosiphum solani* Kalt. (*Myzus pseudosolani* Theo.) and *Myzus circumflexus* Buckt. were also tried, as well as the capsids *Calocoris bipunctatus* Fab. and *Lygus pabulinus* Linn. The different species of aphides were reared separately on crinkle potato plants grown under cellophane cages in the glasshouse. The capsids were allowed to feed on the source of disease for a period of 10 days before being transferred to the experimental plants.

Myzus persicae.—In the first experiment the aphides from crinkle in President were confined under cellophane cages on 8 healthy President plants about 8–10 inches high, on which they were allowed to feed for 17 days. No symptoms resulted either in the current year or in the following one.

The writers have observed during the progress of their experiments that successful inoculation by means of insects appears to be dependent on the age of the experimental plants at the time of colonisation. Current year symptoms were obtained if the aphides were colonised on the sprouts of the healthy tubers, whereas if colonised on plants about 6 inches high symptoms frequently did not appear until the following year. If the experimental plants were larger than this at time of colonisation, they almost invariably failed to become infected.

In a second experiment 4 healthy President plants about 4 inches high were colonised for 10 days with aphides from crinkle in Irish Chieftain and 4 similar plants with aphides from crinkle in President. The plants were derived from half-tubers, the other halves being grown as controls. No disease symptoms developed in the 8 inoculated plants in the current year, but 7 of them became infected, nevertheless, as was shown when their tubers were subsequently planted. A total of 44 plants was present in the following year, of which 33 showed symptoms of a mild, and at times scarcely perceptible,

yellowish mosaic in the tops of the plants. On the older leaves there sometimes appeared yellow isolated interveinal patches which eventually became desiccated and necrotic. The full crinkle symptoms were not reproduced in any case. The infected plants were reduced in size and vigour as compared with the adjacent controls, which were vigorous and maintained a healthy appearance.

In all succeeding experiments with *Myzus persicae,* the aphides were colonised on sprouted half-tubers, the remaining half-tubers being grown as controls. It was observed occasionally that some of the shoots from these inoculated tubers showed symptoms while others appeared healthy, and such plants almost invariably produced mixed tuber units.

In all, 4 experiments were conducted using this technique, of which the results may be presented together. The source of disease was crinkle in President, and on this colonies of *Myzus persicae* were reared and subsequently transferred to sprouted healthy tubers of President to the total number of 32. The insects were allowed to feed on the healthy sprouts for periods varying from 10 to 50 days, as it was at one time thought that the length of the feeding period might influence the subsequent disease symptoms. From the result of the experiment this does not appear to be the case. Nineteen of the 32 inoculated tubers gave rise to diseased plants when grown in the greenhouse. All the controls remained healthy. The result was the development in all the infected plants of a mild mosaic similar to that obtained in the preceding experiment. The initial symptoms were a mild veinal mosaic which began as clearing of the veins. The full crinkle disease was not transmitted in any case. This result was substantiated when tubers from these plants were grown in the following year.

In a further similar experiment 6 President sprouted half-tubers were colonised with *Myzus persicae* from crinkle in Irish Chieftain. When grown in the house, they gave rise to plants all of which displayed symptoms similar to those obtained when crinkle in President was the source of infection. The controls remained healthy.

It is clear from these experiments that crinkle was not transmitted as such by *Myzus persicae.* Evidence will be submitted further on to show that the aphis selectively transmitted one constituent of the crinkle complex namely virus A. So far as the symptoms on President are concerned, the present results resemble closely those of K. M. Smith (24), who, using a crinkle in Myatt's Ashleaf as a source, found that *Myzus persicae* transmitted to healthy President a disease causing only a mild mosaic accompanied by slight crinkling of the leaf surface. Elze (5), on the other hand, recorded the transmission of crinkle between potatoes by the aphides *Myzus persicae, Myzus pseudosolani, Aphis rhamni,* the leafhopper *Eupteryx auratus,* and the fleabeetle *Psylloides affinis.*

Myzus circumflexus.—The insects from crinkle in President were colonised on 4 young healthy President plants with half tuber controls. No symptoms appeared on either inoculated or control plants in the current year, but when the resulting tubers were grown in the field, 75 per cent. of the inoculated

plants showed a mosaic of a mild type similar to that transmitted from crinkle by *Myzus persicae*. The controls remained healthy and were appreciably more vigorous than the infected plants. The nature of the disease transmitted by *Myzus circumflexus* has not been further investigated, but judging from the symptoms on the variety President it has been concluded that it is probably similar to that transmitted by *Myzus persicae*.

Macrosiphum solani.—Inoculations by means of this species were made to 4 young plants and 6 sprouting tubers, but in no case did the insects transmit any disease to healthy President either from President or Irish Chieftain affected with crinkle. The inoculated plants were grown for two years.

Lygus pabulinus and *Calocoris bipunctatus*.—Each species from crinkle in President was colonised on 4 young healthy President plants. No symptoms developed on the inoculated plants either in the current or succeeding years.

Virus A.

This virus, which is carried by most Irish Chieftain plants, has been described by Murphy and McKay (15). They discussed fully the details of their experiments, in which virus A was combined with simple mosaic, interveinal mosaic, and a mosaic present in Up-to-Date, with the production in each case of crinkle symptoms.

Effect of introducing virus A into other potato varieties by graft.

Scions of Irish Chieftain carrying virus A were grafted on healthy President and Arran Victory plants. President developed a very mild veinal mottle, which largely disappeared with the continued growth of the plant. Arran Victory also showed very mild disease symptoms consisting of vein clearing. These results are in agreement with those of Murphy and McKay.

Confirming unpublished results of Murphy and McKay, it was found that, when grafted on British Queen, virus A produced a disease of the acronecrotic type, which invariably resulted in the death of the plant. The tubers from such plants show severe necrosis, which appears to originate in the internal phloem, but rapidly embraces all the tissues, so that the eyes are killed, and in many cases the entire tuber shrinks and rots. Sometimes the necrosis does not reach the rose or bud end of the tuber, so that certain eyes are free from injury.

When grafted on Up-to-Date, virus A produced a necrotic disease (Cf. Murphy and McKay (15)) which eventually killed the plants, and the tubers developed severe necrosis similar to that occurring in British Queen.

It is in this respect clear that virus A behaves exactly in the same way as crinkle, whether derived from President or Irish Chieftain. Following grafting both diseases produce the same lethal necrosis in British Queen and Up-to-Date, while following needle inoculation neither does so. It has also been shown that, in all cases in which crinkle was needle-inoculated to other hosts, whether potato, *Datura Stramonium*, *Nicandra physaloides*, or tobacco, the resultant disease

recovered on President was only a simple mosaic which did not produce necrosis when grafted on British Queen or Up-to-Date. Since it will be shown that in most cases it is impossible to transmit virus A by needle to the other hosts employed, it is obvious that the virus which is dropped from crinkle on needle inoculation corresponds to virus A as occurring in Irish Chieftain. This is substantiated by the fact that typical crinkle symptoms were produced in President by combining virus A with any of the simple mosaic diseases derived by needling crinkle through tobacco, *Datura*, or *Nicandra physaloides* to President, or by needling it direct to healthy President.

Needle inoculation of virus A from Irish Chieftain to other hosts.

Numerous attempts were made to discover a host plant to which virus A could be transmitted by needle, with a view to carrying out experiments on the physical and chemical properties of the virus in extracted sap. The following solanaceous hosts were needle-inoculated with sap from Irish Chieftain containing virus A, the figure in brackets indicating the number of plants in each case:—*Datura Stramonium* (30), tobacco (40), *Solanum Dulcamara* (6), *Nicandra physaloides* (12), tomato (6), capsicum (6), egg plant (6), *Petunia* (6), and British Queen potato (4).

Excluding the inoculations into tobacco, which are dealt with below, no symptoms were obtained in any of the plants, a result which in general contrasted markedly with that obtained when crinkle and mosaic *ex* C were used. The *Datura* and *Petunia* plants inoculated with virus A were tested for the possible presence of latent disease by grafting the former on potato (vars. British Queen and President) and needling from the latter into tobacco, but in both cases a negative result was obtained, and it was provisionally concluded that virus A was not transmitted by needle to these hosts. The fact that crinkle dropped the virus A constituent when passed by needle through *Datura, Petunia,* and *Nicandra physaloides* supports the view that virus A is not needle-inoculable to these plants.

So far as tobacco is concerned it was found in 1932 that symptoms were produced by needle inoculation from Irish Chieftain carrying virus A, although in the preliminary inoculations in 1931 no symptoms had been observed. In 1932 each tobacco plant was grown in a 6-inch pot, and 3 batches of such plants were inoculated with virus A in the months of May, July, and August, respectively. In the first two series, 4 out of the 12 inoculated plants showed vague symptoms of mottling, vein-clearing, and mild green vein-banding, but these were confined to the older leaves and did not become general. Attempts to convey infection from these tobacco plants by needle to 4 British Queen and 2 President plants gave a negative result.

In the third series, 6 young tobacco plants were inoculated with virus A from Irish Chieftain, and at the same time a number of similar tobacco plants were inoculated with crinkle, interveinal mosaic, and mosaic *ex* C. The

conditions for growth and development of symptoms were particularly good at this period. All the inoculated plants, except those needled with virus A, showed clearing of the veins in 7 or 8 days, followed rapidly by the development of conspicuous mottle and ring-spotting. In contrast, the virus A plants appeared normal at this time, except that two of them showed a suspicion of vein-clearing in the pair of leaves above the inoculated ones after about 12 days. This did not become intensified, but the same leaves, after a further period of three weeks, displayed a faint ill-defined mottle. A similar mottle appeared at the same time in the corresponding leaves of two other plants inoculated with virus A, although the preliminary vein-clearing had not been observed in this case. This mottle was followed about 6 weeks later by the development of localised mild green vein-banding. The leaves showing these symptoms were by this time old and very large, but the upper, younger leaves were entirely normal. It was not until the beginning of October, nearly two months after inoculation, that unmistakable vein-banding symptoms appeared in one of these plants, coming out quite clearly in the young growth as well as in the older leaves. By the end of October, four out of the 6 plants inoculated with virus A showed clear symptoms of vein-banding in all the leaves.

A noticeable feature of these inoculations was the slowness of the vein-banding symptoms to become general, a fact which probably explains the earlier more or less negative results. It was found, however, that once the vein-banding disease had established itself in tobacco, inoculation to other tobaccos caused symptoms to develop with relatively great rapidity. Vein-clearing now appeared in the leaves above the inoculated ones after 13 days, and was soon accompanied by distinct vein-banding. This became general all over the plants in less than 3 weeks from the time of inoculation, and was unaccompanied by mottle or ring-spotting of any kind (see fig. 2). No increase in virulence was observed on transfer of the disease through 3 successive series of tobacco plants.

It will be shown that the virus transmitted by *M. persicae* from Irish Chieftain carrying virus A, or from President infected with crinkle, causes vein-banding symptoms in tobacco similar to those just described. Both the aphis-borne and needle-borne vein-banding diseases in tobacco were inoculated by needle into a number of young President plants, including 12 healthy plants, 6 affected with mosaic *ex* C and 4 affected with simple mosaic. The result was the same with both vein-banding diseases, for no apparent change was made in any of the inoculated President plants, so far as can be judged from current season symptoms. (It will be noted that if virus A had been successfully inoculated into plants affected with mosaic *ex* C or simple mosaic, crinkle would have resulted.) Previous experiments have shown that virus A originating from Irish Chieftain or from crinkle is not needle-inoculable to potato, and this negative result, therefore, was to have been expected. On the other hand, it is anticipated that *M. persicae* will probably transmit the virus from tobacco to potato, as it does in the reverse direction and between potato and potato. This work is now in progress.

Although the vein-banding disease in tobacco caused by virus A is symptomatically identical in this host with K. M. Smith's *Y* virus from Up-to-Date (28), it has not produced any symptoms when needle-inoculated to President potato, unlike Smith's *Y* which caused crinkle and leaf-drop streak in this host. It is considered that there must be more than one virus capable of causing vein-banding symptoms in tobacco, and there is a fair amount of evidence that such is the case. Hamilton (6) isolated a virus from *Hyoscyamus* which caused vein-banding in tobacco, but she failed to transmit this disease by needle or by *M. persicae* from the tobacco back to 5 different potato varieties, including President and Arran Victory. Valleau and Johnson (29) isolated a vein-banding virus on tobacco which on return to healthy potato seedlings caused a faint mottle and slight distortion of the leaves, but the reaction to be expected from these seedlings to one or other of the vein-banding viruses is of course unknown. The available evidence, however, indicates that other viruses besides that which causes acropetal necrosis in President can give rise to green vein-banding symptoms in tobacco.

Effect of grafting Irish Chieftain on Datura Stramonium.

Since needle inoculation of virus A from Irish Chieftain to *Datura* had failed to cause infection, some preliminary grafting experiments were carried out in order to see if this host was susceptible to virus A under any conditions. Eight *Datura* plants were grafted with scions of infected Irish Chieftain. The scions made poor union, for, although they lived they did not "grow away," and in two cases small tubers formed at the point of union with the stock, a further indication that the grafts were unsatisfactory. No clear disease symptoms appeared on the *Datura* plants although some of the leaves showed at times uneven shades of green colour. Return grafts were made from a number of these *Datura* plants to 2 President and 4 British Queen potato plants. The *Datura* scions flourished on the potato stocks, and one British Queen developed in the foliage pronounced streak lesions of the acronecrotic type, although the plant was not killed, and some of its tubers were also severely necrotic. This result, although derived from a single experiment, indicates that *Datura Stramonium* accepts virus A when grafting is the method of infection, its presence in the *Datura* being detected by the reaction when the latter was grafted on British Queen. Salaman (22) has recently found that when crinkle is introduced by graft it passes through *Datura* to potato although the full crinkle symptoms did not appear upon the potato stock until the second season. Since crinkle is regarded by the writers as a complex of mosaic *ex* C and virus A, Salaman's result is taken as further evidence that virus A can be transmitted by graft but not by needle to *Datura Stramonium*.

Transmission of virus A by Myzus persicae.

It has been shown that *Myzus persicae* transmitted from crinkle to healthy President a disease characterised by a very mild veinal mottle which bore no

resemblance in its symptoms to the original crinkle. Investigation of this insect-transmitted disease gave the following results :—

I.—When grafted on British Queen and Up-to-Date it caused acronecrosis identical with that induced in these varieties by direct grafts of Irish Chieftain containing virus A. In a few of the grafted Up-to-date plants, while some of the axillary shoots exhibited acronecrosis, the appearance in other shoots was suggestive of acropetal necrosis, since the lower leaves died and remained hanging on the stems, in which the necrosis spread upwards, the tops being last attacked. It was observed that plants behaving in this manner were fairly old when grafted, since young plants always showed typical acronecrosis. In all cases the tubers of both British Queen and Up-to-Date developed severe necrotic lesions during storage.

II.—No visible symptoms were produced on needle inoculation to 17 plants of *Datura Stramonium*.

III.—Twenty tobacco plants (variety White Burley) were needle-inoculated with the disease. Of these, seven developed symptoms which were identical with those obtained on needle inoculation direct from Irish Chieftain potato to tobacco, as already described. They began as a vague mottle, sometimes accompanied by faint vein-clearing, and eventually developed into conspicuous vein-banding. It was not until this stage was reached that there was unmistakable evidence of infection. A notable feature was the length of time, never less than four weeks, before definite symptoms appeared.

IV.—This disease was combined on seven occasions with simple mosaic in President by top-grafting and by core-grafting. In six cases, the combination resulted in the production of crinkle similar to the original crinkle source, just as described by Murphy and McKay for combinations of simple mosaic and virus A (15).

The experiments just described were carried out with the aphis-transmitted disease derived from crinkle. Further experiments which yielded entirely confirmatory results were carried out with the virus secured by *Myzus persicae* direct from Irish Chieftain carrying virus A as follows :—

A.—Six healthy sprouting half-tubers of President were colonised with *Myzus persicae* from Irish Chieftain. These gave rise to plants all of which developed clearing of the veins, followed by a veinal mottle similar to that displayed by the plants colonised with insects from crinkle already described.

B.—When *Myzus persicae* from Irish Chieftain was colonised on White Burley tobacco plants, symptoms developed after twenty-one days consisting of mild vein-clearing and subsequent vein-banding similar to that caused in tobacco by the virus transmitted by *Myzus persicae* from crinkle.

C.—Four sprouting half-tubers of Up-to-Date (streak carrier) were similarly colonised with *Myzus persicae* from Irish Chieftain. About four weeks afterwards the sprouts developed superficial dark elongate blisters over which the epidermis became ruptured, resulting in sunken dark areas from 1–5 mm. in length. When the shoots came above ground after planting, necrotic lesions

were present on the stems, and as the young leaflets unfolded they displayed streak lesions on the midribs and veins which led to distorted growth. (See fig. 4.) By the time the plants were 6–8 inches high, the growing points became necrotic and were rapidly killed, followed soon afterwards by the death of the entire plants. The control half-tubers gave normal plants, as did sprouting tubers of Up-to-Date (streak-carrier) on which non-infective *Myzus persicae* from cabbage had fed for 6 weeks. The result of the experiment is again to identify the virus transmitted by *Myzus persicae* from crinkle, with that obtained by the same agency from Irish Chieftain carrying virus A.

D.—A similar experiment was performed using healthy British Queen instead of Up-to-Date. The sprouts developed lesions similar to those described on the latter. When the inoculated tubers were potted up and produced plants, necrotic patches occurred on the leaves, the undersides of the veins, and on the petioles. The stems also showed necrosis. When the growing points of the plants were removed, the tips of the developing axillary shoots were attacked, and rapidly killed. A similar acronecrotic effect is produced in British Queen by grafting with scions of Irish Chieftain carrying virus A, and also by grafting with scions of President infected by *Myzus persicae* with virus A from crinkle.

E.—The combination of the aphis-transmitted virus from Irish Chieftain with mosaic *ex* C resulted in the development of crinkle as shown by the following experiment—*Myzus persicae* from Irish Chieftain carrying virus A was colonised and allowed to feed for 30 days on 6 sprouted half-tubers of President infected with mosaic *ex* C. Five of the half-tubers gave rise to typical crinkle plants (see fig. 1), while the control half-tubers produced plants showing a definite diffuse yellowish mosaic with no distortion of the foliage (= mosaic *ex* C).

These experiments prove conclusively that the virus selectively transmitted by *Myzus persicae* from crinkle is identical with the virus which occurs naturally in Irish Chieftain to which the name virus A has been given (15). The discovery that virus A is transmissible between potato plants by *Myzus persicae* has made it possible to analyse crinkle for the first time without the intervention of other solanaceous hosts. The constituent viruses of the naturally occurring crinkle complex, *i.e.*, virus A and mosaic *ex* C, have been isolated on President plants by insect transmission and by needle inoculation respectively, and the synthesis of the complex from these constituents has been effectively accomplished in the manner described above.

INTERVEINAL MOSAIC.

Reactions of interveinal mosaic in other host plants.

The source of infection in the following experiments was President affected with interveinal mosaic, the foliage symptoms of which have been described. The disease causes characteristic lesions in the tubers of President which originate

independently in the pith and cortex as brown spots, each surrounded by a translucent area. Microscopic examination shows that the affected areas consist of groups of cells filled with brown granular material, which are much misshapen, with swollen brown and disintegrating walls. The translucent zones are due to the absence of starch from the peripheral cells, but the centre of the necrotic spot is always occupied by a small group of cells filled with large starch grains. During storage the necrosis spreads, more particularly in the outer layers of the cortex, which shrivel up so that eventually the surface of the tuber becomes dry, corrugated and discoloured. The necrosis sometimes invades the vascular tissue, but not to any appreciable extent, and the affection is primarily, and in its origin, one of the cortex and pith. The eyes are not injured. The tuber lesions caused by aucuba mosaic in President are very similar.

Potato (var. Arran Crest).—Necrotic lesions developed on the inoculated leaves after 5 days and a few days later the growing points were affected and the plants were rapidly killed by streak of the acronecrotic type.

Tobacco (variety White Burley).—Infection was secured readily when tobacco was inoculated with interveinal mosaic by needle. The symptoms took the form of a preliminary clearing of the veins followed rapidly by the development of numerous chlorotic spots and concentric rings all over the leaves, and later of some necrotic spotting and vein-banding in the older leaves. The symptoms were very similar to those produced by crinkle in tobacco, if anything slightly more severe.

The disease was re-inoculated by needle from tobacco to 4 young healthy President plants, 3 of which developed an intense interveinal mottle indistinguishable from that in the original President source. Furthermore, the tubers of these plants developed the characteristic necrotic lesions during storage. The fourth plant of the batch had a less intense mottle, although of the interveinal type.

A single passage through tobacco, therefore, did not cause any perceptible alteration of the interveinal mosaic disease. K. M. Smith (26), however, records the fact that repeated passage through successive tobacco plants of the virus of interveinal mosaic caused a marked increase in virulence, with the result that when it was returned to healthy President plants, the latter developed a virulent streak, which almost entirely overshadowed the interveinal mosaic. He observed that the severity of the streak developing on potato appeared to be directly correlated with the number of progressive needle inoculations through tobacco.

Datura Stramonium.—Infection also occurred readily when interveinal mosaic *ex* President was needle inoculated to *Datura*. The symptoms are very similar to those caused by crinkle in this host, but are generally somewhat more severe.

The disease was returned to potato from *Datura* by grafting infected *Datura* scions on 4 healthy President plants (needle inoculation was not tried). The stock plants developed a pronounced mottle which rapidly developed into typical

interveinal mosaic. The tubers were affected with the characteristic necrotic lesions, and when grown in the following year displayed interveinal mosaic identical in its appearance, and in its reactions on tobacco and *Datura*, with that in the original President plant used as source of infection.

Petunia.—The first batch of 4 *Petunia* seedlings inoculated early in 1932 with interveinal mosaic *ex* President failed to become infected. A second series of 4 plants was inoculated with interveinal mosaic *ex* President which had been passed through *Datura* as described above. These *Petunia* plants, as well as the uninoculated controls, displayed the usual mottled appearance but no disease symptoms were distinguished on them. However, a mixed inoculum from the 4 plants was needled into 3 tobacco seedlings, with the result that all 3 tobaccos developed conspicuous symptoms, consisting of a preliminary clearing of the veins, followed by pale spotting, mottle, necrotic specks, and later on by dark green vein-banding. The control *Petunia* plants produced no symptoms on inoculation to tobacco.

On re-inoculating from the above infected tobacco plants to young, actively-growing healthy President plants, interveinal mosaic identical with that in the original President source was obtained, and the tubers developed the characteristic necrotic lesions during storage. Furthermore, inoculations were made from these infected tobacco plants to *Datura* and back again to tobacco, and the symptoms characteristic of interveinal mosaic were obtained in each host.

Later in the summer, a third batch of *Petunia* seedlings was inoculated with interveinal mosaic *ex* President. This time, 2 out of the 4 inoculated plants developed conspicuous disease symptoms, consisting of a preliminary clearing of the veins, which later assumed a vivid yellow colour. Bright yellow spots and numerous small concentric rings appeared between the veins, and as the plants grew older these symptoms became more intense. Later on many of the leaves became a brilliant yellow colour, except for occasional patches of dark green in the interveinal areas or bands of green bordering the main veins. (See fig. 7.) Even the sepals of the flowers displayed bright yellow mottle and ring-spotting.

This disease was needle-inoculated from *Petunia* to tobacco and *Datura*, both of which developed conspicuous symptoms. In tobacco, concentric rings on the inoculated leaves were followed by pronounced ring-spotting and subsequent green vein-banding, the symptoms resembling those obtained by inoculation of interveinal mosaic direct from potato to tobacco. In *Datura*, symptoms consisted of vein-clearing and pale spotting, followed by pronounced interveinal chlorosis and subsequent green vein-banding, the symptoms in this case also resembling those obtained by direct inoculation from interveinal mosaic in potato. It is clear from these experiments that *Petunia* cannot be relied upon as a filter plant which rejects viruses of the ring-spotting type (*X*) and extracts the vein-banding *Y* virus from any complex containing that element. (Cf. Smith (28).)

Nicandra physaloides.—Healthy *Nicandra* seedlings were readily infected by needle with interveinal mosaic. Symptoms, consisting of chlorotic mottling accompanied by necrotic spots, were obtained which resembled those caused by needle inoculation of crinkle to this host.

When scions from these infected *Nicandra* plants were grafted on healthy President, the latter developed a pronounced mottle, which rapidly became identical with the interveinal mosaic in the original President source. The tubers showed characteristic lesions during storage, and when grown in the following year produced typical interveinal mosaic plants. This disease gave rise to crinkle when core-grafted with Irish Chieftain containing virus A (cf. Murphy and McKay (15)). The tubers of these synthetic crinkle plants also displayed the necrotic lesions characteristic of interveinal mosaic.

Attempt to transmit interveinal mosaic by Myzus persicae.

Four actively-growing seedlings of *Nicandra physaloides* were colonised with *Myzus persicae* which had been reared on President affected with interveinal mosaic. The insects fed well, and after 14 days the cages were lifted, and the insects removed. The plants grew to a large size but showed no symptoms. Scions from each of these *Nicandra* plants were grafted on young healthy President plants on which they grew vigorously, but no current-season symptoms developed in the potato stocks. The evidence therefore indicates that interveinal mosaic is not transmissible to *Nicandra physaloides* by *M. persicae.* Attempts to transmit interveinal mosaic from potato to tobacco by means of *M. persicae* also failed.

The results of the foregoing experiments suggest that interveinal mosaic is not of dual nature, as attempts to isolate a *Y* virus from the disease ended in failure; on the other hand, the virus can be passed through a number of plants, including *Datura,* tobacco, *Petunia,* and *Nicandra,* without undergoing any perceptible changes. The technique which enabled K. M. Smith (28) to show the complex nature of several potato virus diseases, and also that by which the writers analysed crinkle into the two constituent viruses, have failed to show the complexity of interveinal mosaic. The possibility must always be considered, however, that the presence of necrosis in the tubers, and to a certain extent in the foliage, of President plants affected with interveinal mosaic is perhaps indicative of a second virus in addition to that causing the mottle. Smith (26) entertained such an idea in considering the virulent streak disease which he obtained by repeated passage of the interveinal mosaic virus through tobacco, suggesting that the tobacco possibly liberated a streak virus which accompanied the interveinal mosaic in a comparatively latent state in the potato.

STREAK.

Reactions of the streak carried by Up-to-Date in various hosts.

Potato (*a*) *Effect of grafting.*—The stock of Up-to-Date plants used in these experiments carries a virus which produced a violent acronecrosis (top-necrosis) when introduced to President or Arran Victory by grafting, symptoms appearing on an average after 21 days.

In grafting experiments of this kind, one usually finds that if good union is not effected between scion and stock, the former may live for a considerable period, but fails to grow away properly, and in such a case the disease frequently does not infect the stock plant. In one of the writers' experiments, an Up-to-Date scion was grafted on a President stock, but union was evidently poor, for although the scion lived and remained turgid it made very little growth. A small tuber, however, developed at the base of the scion, and in the course of 7 weeks after grafting, attained a diameter of 1 cm. During this time the stock plant grew vigorously, but showed no symptoms of any kind. The tuber was then removed from the base of the scion, and ten days later numerous streak lesions appeared in the President stock, which spread rapidly all through the plant, so that the latter was soon killed outright. It appeared that the removal of the tuber was directly connected with the appearance of the disease in the stock, and unless the result was merely a coincidence, which is considered unlikely, it could be interpreted as evidence that this virus travels through the plant with the food stream only. The formation of the tuber indicated that the elaborated sap from the scion was not passing into the stock, although a supply of water in the opposite direction must have been maintained, and it was only when the removal of the tuber forcibly directed the food stream into the stock plant that the virus entered the latter. Caldwell ((3), (4)) has shown that the active agents of certain virus diseases of tomato do not travel with the water stream through the xylem vessels, and he concluded that movement takes place through any of the living ground tissue of the plant without localisation to the phloem elements.

(*b*) *Effect of needle inoculation.*—Inoculations were made by needle from streak-carrying Up-to-Date to three healthy President plants which had just come above ground, and similar inoculations were made to three sprouting tubers of Arran Victory. The plants grew well but no symptoms developed in them. So far as the writers are aware there is no record of the transmission of the acronecrotic virus from Up-to-Date to healthy President potato by needle, notwithstanding that infection is readily secured by grafting. It will be seen, however, that a certain measure of success was attained when President was needle-inoculated from tobacco infected with streak from Up-to-Date. In the variety Arran Crest inoculation with sap from streak-carrying Up-to-Date induced a lethal acronecrotic streak.

Tobacco (var. White Burley).—Several batches of young tobacco plants were inoculated by needle from Up-to-Date carrying streak during the summer

of 1932. Compared to the effects of interveinal mosaic and crinkle on tobacco, the symptoms produced by streak were mild and usually slow in appearing, and resembled more closely those caused by simple mosaic. (Fig. 9.) At best, vein-clearing appeared ten days after inoculation, and subsequently a nebulous ring-spotting developed, accompanied in one or two cases by a number of fine necrotic specks. The mottle gradually became more pronounced but the necrotic symptoms were confined to one or two leaves. Finally the older leaves developed green vein-banding. The symptoms were considerably milder than those recorded by Smith (28) in similar experiments with Up-to-Date carrying streak.

Needle inoculations were made from the above-mentioned streak-infected tobacco plants to 10 healthy President plants, of which 4 alone showed symptoms, the unit control plants remaining healthy. Two of the President plants developed nothing more than a number of brown lesions on the leaflets of the side shoots, the tops of the plants having been cut to promote development of the latter. This necrosis, however, was confined to a few leaves, and did not spread to the growing points. The third infected plant showed more pronounced symptoms. There was no evidence of infection for 3 weeks after inoculation, at which time the top was cut in order to force the axillary shoots into growth. The two upper shoots displayed a number of severe veinal necrotic lesions on the leaflets and petioles, and brown streaks also appeared in the main stem. Some of the leaves were killed, but the actual growing points were not involved. It was observed that on the slowing down of the growth of the plant previous to maturity, the spread of the necrosis apparently ceased. The fourth plant to become infected was very young at the time of inoculation. After 3 weeks it was observed that a minute axillary bud in the axil of an inoculated leaf was dead, and a brown streak extended from this bud to the node of the leaf above. Otherwise the plant looked perfectly normal and was growing actively. The top of the plant was then cut away with the result that side shoots grew rapidly. The first and second axillary shoots developed typical acronecrosis and were killed outright; the third and fourth shoots displayed numerous brown lesions together with severe mottling and puckering of the leaflets, but they were not killed. The growth of the plant was negligible by the time this stage was reached, and the symptom picture remained unchanged until the plant matured. The tubers of this and the other infected plants were practically free of streak lesions.

The results show that it is possible, though difficult, to needle-inoculate Up-to-Date streak from tobacco to President potato. In order to secure infection it is especially essential that the potato plants should be very young and actively growing at the time of inoculation, and even then the disease may not develop unless the plants are stimulated to the continued production of new foliage. In any case, judging from the experiments described above, the disease recovered in President does not attain the virulent form which usually follows grafting with Up-to-Date scions. Inoculations were made by needle from one

of the streak-infected President plants described above to 4 healthy young *Datura* plants, all of which developed a pronounced yellowish mottle. A scion from one of these infected *Datura* plants was grafted on a healthy President plant, and the latter in due course developed a number of streak lesions of the acronecrotic type, but the disease was not virulent and the plant was not killed.

In order to test whether the apparent reduction in virulence of the streak virus took place in the tobacco host, inoculations were made from infected tobacco plants to a number of healthy *Datura* plants. Symptoms of vein-clearing, mottle, and subsequent green vein-banding, were obtained, and on grafting scions from these *Datura* plants to 2 healthy President and 1 Arran Victory, all 3 potato stocks developed typical acronecrosis which rapidly killed the plants. The streak virus, therefore, was not attenuated by successive passage through tobacco and *Datura* and thence to potato by graft.

Datura Stramonium.—Several batches of healthy young *Datura* plants were inoculated by needle from Up-to-Date carrying streak. In many cases the Up-to-Date sap was previously filtered by passing it through compressed paper pulp and subsequently through L 1, L 3, and L 5 Pasteur Chamberland filter candles. All apparatus was sterilized before use, and the filter candles were tested with *B. prodigiosus*. Both the unfiltered and all grades of sap from filtered Up-to-Date caused similar symptoms in Datura, which began to develop 7–9 days after inoculation, and consisted of vein-clearing, pale spotting, occasional necrosis of the fine veins of the leaf, and subsequent interveinal chlorosis and green vein-banding. The symptoms resembled those caused by crinkle in *Datura,* but were generally less severe.

Needle inoculations from these *Datura* plants to 4 healthy President plants caused no symptoms beyond a few reddish lesions on the inoculated leaves, and, in order to prove whether the acronecrotic streak virus was present in the *Datura* plants, scions were taken from them and grafted on President potato plants to the total number of 17. Eleven of these developed acronecrosis identical with that produced by a direct graft from the Up-to-Date carrier. (See fig. 5.) Symptoms began to appear in times varying from 9–13 up to 36 days, the average period being about 21 days after grafting. In the majority of cases, the axillary shoot below the scion showed the first symptoms, consisting of very fine brown specks all over the leaflets, which on close examination were seen to be connected with the minute veins of the leaf. On decolorising in alcohol, and treating with iodine in the manner described by Holmes (7), it was observed that each microscopic brown speck on the leaflets was surrounded by an area in which starch was concentrated, and furthermore, that the concentration of starch apparently *preceded* the development of the necrotic speck in each case (see fig. 6), so that the iodine treatment showed up a number of points of infection which were not visible on the green leaf.

The necrotic specks increased rapidly in size and number, so that in the course of a few days the entire young shoot was killed. Each successive axillary

shoot down along the stem became affected in a similar manner, and eventually the plant was killed outright. Occasionally, when the lowest shoots had grown fairly large before becoming infected, they were not killed, but displayed a mottle accompanied by severe streak lesions, many of which were surrounded by a halo of chlorotic tissue. In the majority of cases, however, infection took place rapidly, and the plants were killed by necrosis without showing any mottle on the leaves.

Six of the President plants grafted in this way showed no symptoms. In 3 cases this could be accounted for by the fact that the scions made poor union, but in the remaining 3 the *Datura* scions grew vigorously, and the failure to secure infection is not understood. It should be emphasised that the *Datura* scions causing acronecrosis in potato included some of those which had been inoculated with sap passed through L 1, L 3, and L 5 filter candles.

So far as the writers are aware, these experiments prove directly for the first time that an acronecrotic virus of the type carried by Up-to-Date is filterable and inoculable by needle. Other workers, including Van der Meer (9), K. M. Smith (28), Silberschmidt and Quanjer (19), have obtained symptoms in such hosts as *Datura Stramonium*, tobacco, and tomato, on inoculation from different potato varieties containing a similar latent acronecrotic virus, but since none of them recovered the virus on potato, and since the possibility exists that a mosaic virus additional to the streak might be responsible for the symptoms in these hosts, their experiments did not prove conclusively the transmissibility by needle of the acronecrotic virus.

Petunia (Garden variety).—Seven *Petunia* plants were inoculated by needle from streak-carrying Up-to-Date, but no disease symptoms were observed on them. After several weeks further inoculations were made from these *Petunia* plants to 8 healthy young tobacco plants in order to test for the possible presence of a virus corresponding to Smith's *Y*. No symptoms appeared on the tobacco plants, and a similar negative result was obtained when inoculations were made from the latter to 2 healthy young President plants.

Attempted insect transmission of streak from Up-to-Date.

Seven sprouting tubers of healthy President were colonised with *Myzus persicae* which had been reared on an Up-to-Date streak carrier, but the inoculated tubers gave rise to normal plants without any trace of disease.

Datura Stramonium was chosen as an alternative host, on account of its susceptibility to the streak virus. The same insects (*M. persicae*) from Up-to-Date were colonised on 6 young *Datura* plants, and allowed to feed for 10 days. Although the insects throve, no disease symptoms appeared on the *Datura* plants, and no infection was secured when scions of the latter were grafted on healthy President plants.

The foregoing experiments substantiate the statement of Quanjer (17) that this type of acronecrotic virus is not transmissible by insect. Furthermore,

the available evidence indicates that the stock of Up-to-Date employed does not harbour a *Y* virus similar to that occurring in the Up-to-Date used by K. M. Smith.

DISCUSSION.

On considering the various diseases dealt with in the foregoing work, it becomes apparent that crinkle is distinguished from the others chiefly by reason of the ease with which its compound nature can be demonstrated. In this respect it resembles the American rugose mosaic, which has been synthesised by Valleau and Johnson (29), Koch (8), and Burnett and Jones (2). K. M. Smith (27) was the first to suggest that many of the potato diseases known as mosaic, crinkle, and streak, are composite in nature. He advanced the theory that the two viruses, *X* and *Y*, which he isolated on tobacco from various infected potato plants are responsible either alone or in combination for the majority of the potato mosaic diseases. The *Y* virus was found to be constant in its symptoms, but *X* was found to be variable, and Smith considered that the different symptoms exhibited by the various potato mosaics were due to combinations of the variable *X* with the stable *Y*, rather than to distinct and separate viruses.

It has been shown in the present study that the viruses underlying crinkle, *i.e.*, virus A and the virus of mosaic *ex* C, can be isolated from the complex on healthy potato plants by insect and needle transmission, respectively, and that crinkle may be re-formed by merely combining these two viruses again in the same plant. It is interesting to compare the analytical products of the naturally-occurring crinkle with the *X* and *Y* viruses described by Smith. The simple mosaic element from crinkle is not transmitted by *Myzus persicae*, but is readily transmissible by needle, and causes symptoms of the ringspot or mosaic type in tobacco, *Datura Stramonium*, and other solanaceous hosts. In general, it corresponds closely with Smith's description of the *X* virus. Virus A, on the other hand, is transmissible by *M. persicae* and inoculable by needle to tobacco, in which it causes symptoms of green vein-banding. To this extent it corresponds with the *Y* virus, but nevertheless the two viruses are not identical. In the first place, *Y* is readily inoculable by needle to potato and certain other hosts, but this is not true of A; *Y* produces severe acropetal necrosis in President potato, while A causes only a transient veinal mottle in this variety. Furthermore, Salaman has shown that the *Y* virus in combination with "reduced crinkle" (= mosaic *ex* C) in President potato does not form crinkle as would virus A under the same circumstances. Notwithstanding that the A and *Y* viruses are definitely not identical, it is clear that they bear a relationship to each other, and that they are quite distinct from the *X* type. The vein-banding virus isolated by certain American workers (2), (8), (29), also corresponds with the *Y* and A viruses in its symptoms on tobacco and in being transmissible by *M. persicae*. It is likely that it will be found identical with Smith's *Y*, but exact identification is impossible until the two are compared on similar varieties of potato.

Actually, the *Y* virus has not been found to underlie any of the diseases dealt with in the present work. Furthermore, simple mosaic, mosaic *ex* C, interveinal mosaic, and the latent acronecrotic streak of Up-to-Date, have not so far yielded any direct evidence of a dual nature involving *X* and *Y*. The Arran Victory mosaic studied by Smith, and found by him to be a complex of the *X* and *Y* viruses, is therefore not identical with the simple mosaic used in this laboratory, although the latter occurred originally in Arran Victory. In Smith's terminology, the writer's simple mosaic, like mosaic *ex* C, would correspond to a simple *X* infection. According to Salaman (22), the interveinal mosaic used by Smith and himself, which Salaman stated contains both the *X* and *Y* viruses, was obtained from Professor Murphy, and it might therefore be expected to be identical with that used in the present work. Our results, however, demonstrate that interveinal mosaic behaves as a single entity, and that the *Y* virus is not associated with it because (*a*) *M. persicae* failed to transmit a *Y* virus from interveinal mosaic to tobacco, and (*b*) the disease is inoculable by needle to *Datura Stramonium*, and can be recovered unchanged from this host on potato. If it were a complex of *X* and *Y*, the disease, according to Smith, should be altered by passage through Datura, owing to the removal of *Y* which is non-inoculable to this host.

Incidentally, interveinal mosaic is (as has been shown) inoculable to *Petunia*, then to tobacco, in which it induces ringspot symptoms, and from the tobacco it may be recovered without apparent change on President potato. The ability to infect *Petunia* has been described by Smith (28) as a property of the *Y* virus which distinguishes it and enables it to be separated from the *X* virus, but the above results with interveinal mosaic demonstrate that a virus which subsequently produces typical "*X*" symptoms in tobacco, and which, in its general reactions, conforms to the *X* type, can pass through certain varieties of *Petunia* at least.

The acronecrotic streak virus carried symptomlessly by Up-to-Date shows no evidence of an underlying *Y* virus, since it is filterable, inoculable by needle to *Datura Stramonium* and tobacco (in which it causes ringspot), and non-transmissible by *M. persicae*. It has all these features in common with Smith's virus *X*, although distinguishable from the typical *X* by its severe effect on President and Arran Victory potato. Murphy and McKay (15) and Murphy (14) believed that this stock of Up-to-Date contained a simple mosaic in addition to streak, but it is considered that the experiments described in the present work do not substantiate this view. If simple mosaic were present in addition to streak one would expect that, being a more easily transmissible disease than streak, it would be isolated from the latter in the course of cross-inoculation and grafting experiments with different solanaceous plants. Actually, in those cases in which streak failed to infect, and in circumstances under which simple mosaic would normally have been transmitted, the experimental plants showed no disease.

It is provisionally concluded that only one virus—that of acronecrotic

streak—is present in this stock of Up-to-Date, and that the mosaic symptoms produced in tobacco and *Datura* by inoculation with this Up-to-Date sap are the manifestation of the streak virus, and not of an accompanying simple mosaic. If this assumption is correct, it would follow that the acronecrotic streak virus is capable of combining with virus A to form a type of crinkle, since Murphy and McKay (15) showed that a crinkle was produced by grafting the Up-to-Date "streak" carrier on Irish Chieftain containing virus A.

K. M. Smith (28) isolated the *X* and *Y* viruses from streak-carrying Up-to-Date plants which exhibited no symptoms, and he concluded that Up-to-Date streak was a virus complex consisting of *X* and *Y*, with possibly a third additional virus. Following Smith, Salaman and Bawden (23) stated that the top-necrosis disease latent in Up-to-Date is a complex of *X* and *Y*, and that possibly *Z* was the third constituent. Murphy (14) criticised Smith's work on the grounds that the *X* and *Y* viruses which the latter isolated from Up-to-Date on tobacco were not necessarily the analytical products of streak, owing to the possibility that more than one disease might have been present in the Up-to-Date, and that the analysis of streak should be confirmed by a synthesis of the same disease in its original host. Point is lent to this criticism by the attempts of Salaman (22) to synthesise a number of the common potato diseases, believed by him to be complexes, by combining the *X* virus with *Y* or *Z* (or both) in healthy potato plants. Only in the case of crinkle, apparently, did the synthetic product resemble the naturally occurring disease, for in practically all the attempted syntheses which involved the introduction of *Y* to President or Arran Victory, this virus produced its characteristic acropetal necrotic effect on the potato plant irrespective of the other viruses with which it was combined.

It has not been proved by synthesis that the Up-to-Date used at Cambridge carries a "streak" which is a complex of *X* and *Y*, and while it is clear that the Cambridge stock of Up-to-Date differs from that studied by the writers in so far as it contains the *Y* virus, it is not necessary to conclude as yet that the *Y* virus is a constituent of this streak, or that the acronecrotic streak virus is different in the two stocks of Up-to-Date.

One of the most interesting results of recent work (22) (28) on potato diseases is the discovery that a potato plant (*e.g.*, Up-to-Date) may carry a complex containing the *X* and *Y* viruses and yet, on further infection with what is held to be the same *Y*, develop severe acropetal streak. This would indicate that in certain virus complexes each constituent virus is so influenced by its association with the other that it ceases to exert its individual effect. The phenomenon has been discussed by Salaman (22), who suggests that "a virus complex is not a mere mixture but a more or less specific grouping of virus entities, united in such a manner that the resultant group acts as a whole, and excites reactions because of the characters which have come to it by reason of the specific grouping of its constituent units."

While this theory appears to be upheld by the behaviour of those complex diseases from which the *Y* virus has been isolated, the writers are not in

agreement with Salaman that crinkle is a composite disease of this type. Salaman, in favour of his argument, points out that the symptoms of the crinkle complex in President are quite distinct from the symptoms of either of its constituent viruses alone, but this appears to be the only reason for regarding crinkle as anything but a free and unassociated mixture of viruses. It does not necessarily follow, however, that, because the combined symptoms of virus A and simple mosaic in a variety such as President give the more severe symptoms of crinkle, the two viruses have become merged together in such a way as to lose the power of independent action within the host. (The case in which a virus complex shows distinctly milder symptoms than those of its constituent viruses is an entirely different matter.) Apart from the special symptom picture there is no evidence that virus A and simple mosaic do not exist free in crinkle, for it has been shown by the reactions of crinkle that each constituent virus exerts its specific and characteristic reactions in all the test plants used irrespective of the presence of the other. The ease with which crinkle can be analysed and synthesised also points to its being a mixture of viruses rather than a compound. Finally, types of crinkle can be produced in President and other varieties by combination of viruses which are not identical. Murphy and McKay (15) synthesised crinkle by the addition of virus A to (*a*) simple mosaic, (*b*) interveinal mosaic, (*c*) a mosaic in streak-free Up-to-Date, and (according to the present writers' interpretation), (*d*) the acronecrotic streak virus carried by Up-to-Date; while Salaman (21) (22) synthesised crinkle from "reduced crinkle" (= mosaic *ex* C) and the *Z* virus which he isolated from paracrinkle. Rugose mosaic, apparently a similar type of complex to crinkle, has been synthesised by Burnett and Jones (2) from a mixture of the vein-banding disease with two different mosaic diseases latent in apparently healthy American potato plants.

Murphy and McKay (15) pointed out that, in their experiments, the crinkle diseases formed by the combinations listed above displayed slight differences in the intensity of their symptoms, but that nevertheless, a definite crinkle disease resulted in each case. It is evident that crinkles of the type under consideration can be formed by combining viruses which are not-identical but which probably belong to *a particular type*. Virus A has been used as one constituent in all the crinkle diseases synthesised in the experiments of Murphy and McKay and of the writers. Salaman used the virus *Z* instead of virus A to synthesise a crinkle, and, while the writers have not worked with virus *Z*, this is possibly an indication that *Z* and A are of similar type. Again the viruses which have been combined with A (or *Z*) to form crinkle have definite characteristics in common, which relate them to one another and at the same time distinguish them from A, viz., they are transmitted by needle but not by *Myzus persicae*; they cause symptoms of ringspot on tobacco and a mosaic mottle on being needled into *Datura Stramonium*. In addition they cause acronecrosis in the potato variety Arran Crest (cf. Murphy, 14), and, finally, the majority and probably all of them are filterable through an anti-bacterial filter and possibly have other

physical properties in common. Broadly speaking, they conform to the type which Smith (28) has designated as *X*.

It has already been pointed that the A virus bears a definite similarity to Smith's *Y* virus. According to Quanjer's (17) system of classification, and also in Salaman's (23) modification of it, Smith's *Y* and virus A would fall into different groups, since *Y* causes acropetal necrosis in President, etc., and A induces top-necrosis (acronecrosis) in British Queen and Up-to-Date. The writers venture to suggest that this arrangement would be somewhat artificial as there appears to be a natural relationship between viruses which are transmissible by *M. persicae*, are non-inoculable to *Datura*, and cause vein-banding in tobacco. In other words the writers consider that the *X* and *Y* viruses to which Smith drew attention are the representatives of two natural and distinct groups of potato mosaic viruses. Whether Salaman's *Z* virus belongs to the *Y* type or is representative of still another group, remains to be determined.

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SUMMARY.

The potato diseases known as simple mosaic, interveinal mosaic, crinkle, and Up-to-Date streak, are described, and an account is given of the effects produced on inoculation of each disease into other solanaceous hosts, *e.g.*, tobacco and *Datura Stramonium*.

Simple mosaic is transmissible by needle but not by *M. persicae*, to tobacco, *Datura Stramonium*, and certain other solanaceous hosts. It is also similarly inoculable to potato and causes top-necrosis (acronecrosis) in the variety Arran Crest.

Crinkle is transmitted in full from potato to potato by grafting, but needle inoculation transmits only one constituent of the complex to healthy President, viz., a simple mosaic which is referred to as mosaic *ex* C.

On passage of crinkle by needle through tobacco, *Datura Stramonium*, *Nicandra physaloides*, and *Petunia*, and back to President potato, a mosaic disease, which is considered identical with mosaic *ex* C, is obtained, and the full crinkle disease is not transmitted.

Mosaic *ex* C corresponds to simple mosaic in its general reactions, and the differences between the two diseases which have been observed up to the present are in degree rather than in kind.

The second constituent of crinkle is transmissible by grafting but not by needle inoculation from potato to potato. It is, however, transmitted from the crinkle complex by the aphis *M. persicae,* which fails to transmit the mosaic *ex* C constituent.

This aphis-transmissible constituent of crinkle causes a transient veinal mottle in President and top-necrosis in the potato varieties British Queen and Up-to-Date. It is shown to be identical with the A virus which occurs naturally in an almost latent condition in Irish Chieftain potato.

Virus A is transmissible by *M. persicae* and by needle to tobacco, in which it causes green vein-banding. It has not been transmitted by needle from tobacco to potato.

Virus A is transmissible to *Datura Stramonium* by grafting, but is non-inoculable by needle to this host or to a number of other solanaceous plants.

A crinkle disease, identical with the naturally-occurring product, is formed when virus A is combined with mosaic *ex* C in healthy President potato.

Interveinal mosaic is inoculable by needle to other solanaceous hosts, *e.g.,* tobacco, *Datura Stramonium,* and *Petunia,* from each of which it can be recovered, apparently unchanged, on President potato. It is also inoculable to potato, causing top-necrosis in the variety Arran Crest. In combination with virus A in President, interveinal mosaic forms crinkle identical in its foliage symptoms with the naturally-occurring disease but showing in addition the tuber lesions characteristic of interveinal mosaic in President.

The latent acronecrotic streak virus of Up-to-Date is filterable and inoculable by needle to *Datura Stramonium* and tobacco. The streak virus is transmissible from *Datura Stramonium* to potato by grafting, but not by needle inoculation. It is also transmissible by needle from Up-to-Date to Arran Crest potato in which it produces top-necrosis.

It is suggested that only one virus, that of acronecrotic streak, is present in this stock of Up-to-Date.

The question of the composite nature of potato virus diseases is discussed. The theory is advanced that crinkle is a mixture, rather than a compound, of two viruses each of which belongs to a distinct type. The A virus is of similar type to Smith's *Y* virus, although definitely distinct from the latter, while the other constituent of crinkle corresponds to Smith's *X* type. It is suggested that all the viruses under consideration fall into two natural groups of which Smith's *X* and *Y* viruses may be taken as types.

DESCRIPTION OF PLATES.

Plate 48.

Fig. 1.—President potato plant showing typical crinkle as a result of infection with virus A and mosaic *ex* C, transmitted by *Myzus persicae* and by needle respectively.

Fig. 2.—Leaf of White Burley tobacco infected by needle scratch with virus A from an apparently healthy Irish Chieftain potato plant. Note the green vein-banding which is preceded by "clearing of the veins." The aphis, *Myzus persicae* Sulz. transmits this virus to tobacco from crinkle-infected President and Irish Chieftain as well as from apparently healthy Irish Chieftain potato plants.

Fig. 3.—Leaf of a President potato plant inoculated by needle from crinkle-infected President. This is the simple mosaic disease referred to in the text as mosaic *ex* C.

Fig. 4.—Young Up-to-Date potato plant infected with virus A by means of the aphis, *Myzus persicae*. This plant shows top-necrosis (acronecrosis) which eventually proved fatal.

PLATE 49.

Fig. 5.—Effect of grafting healthy President potato with a scion of *Datura Stramonium* inoculated by needle with filtered sap from streak-carrying Up-to-Date. Note the top-necrosis in the axillary shoots of the stock plant.

Fig. 6.—Leaflet from a President plant similar to that shown in Fig. 5, taken when the minute primary streak lesions were first beginning to appear and tested for starch by the iodine method. The concentration of starch in the vicinity of each necrotic speck is demonstrated.

Fig. 7.—Leaf of *Petunia* (var. Rosy Morn) infected by means of the needle with interveinal mosaic from President.

Fig. 8.—Leaf of White Burley tobacco infected by means of the needle with mosaic *ex* C from President (see fig. 3).

Fig. 9.—Symptoms produced in White Burley tobacco as a result of needle inoculation from a streak-carrying Up-to-Date potato plant.

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FIG. 1.

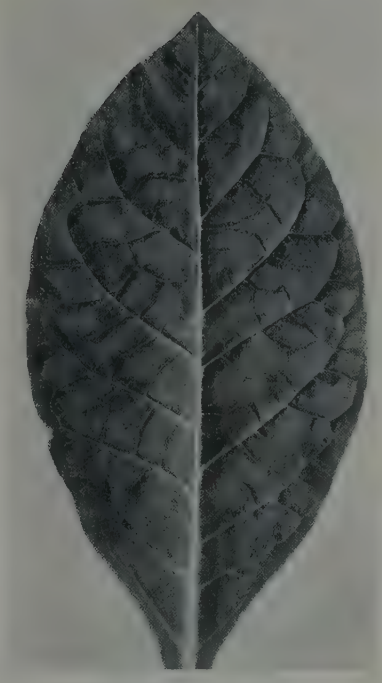

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

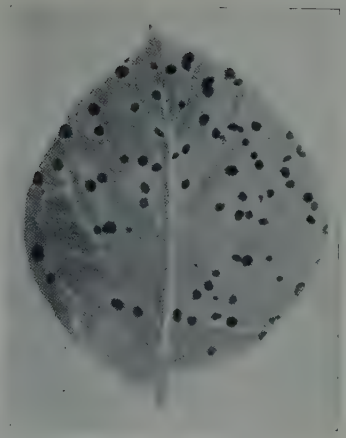

FIG. 6.

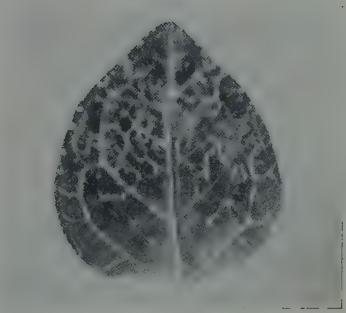

FIG. 7.

FIG. 8.

FIG. 9.

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